155. λ CYG = STT 413 = WDS J20474+3629AB

Table 9.155 Physical parameters for λ Cyg

STT 413	RA: 20 47 24.538	Dec: +36 29 26.57	WDS: 74(405)	
V magnitudes	Aa: 5.4	Ab: 5.8	B: 6.26	
$(B-V)$ magnitudes	Aab: −0.12	B: −0.03		
μ	+14.71 mas yr^{-1}	±0.32	−8.96 mas yr^{-1}	± 0.49
π	4.24 mas ± 0.43 mas	769 light yr	± 78 light yr	
μ(A)	18.58 mas yr^{-1}	± 0.88	−7.56 mas yr^{-1}	± 0.60 (DR2)
π(A)	4.99 mas	± 0.34	654 light yr	± 45 (DR2)
Spectra	Aa:	Ab:	B:	C:
Luminosities ($L_\odot$)	Aa: 230	Ab: 160	B: 100	
Catalogues	HR 7963	HD 198183	SAO 70505	HIP 102589
DS catalogues	H 6 32 (AC)	STT 413 (AaAb-B)	MCA 63 (AaAb)	BDS 10533 ADS 14296
Radial velocity (A/B)	−23.20 km s^{-1}	± 1.1 km s^{-1}		
Galactic coordinates	78°.084	−4°.338		

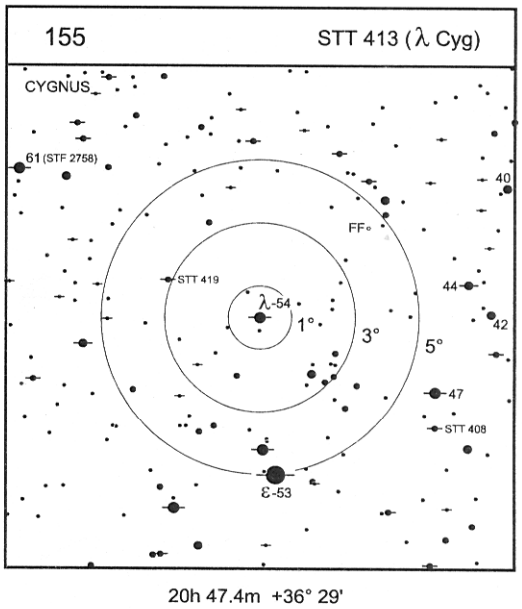
History

Sir William Herschel first noted the ninth magnitude star C at a distance of 'about 1 min.' from λ on 20 September 1781. The close pair, forming AB, was discovered by Otto Struve, using the 15-inch refractor at Pulkovo in 1842. The slow initial motion of this pair led Burnham to doubt whether it was a physical pair, although an orbit with period 93 years was published when only 50° of the apparent orbit had been traversed and the motion in separation looked linear.

The Modern Era

H. McAlister [602] and colleagues resolved the primary component in 1978 using the 4-metre Mayall reflector at Kitt Peak. The two components form a binary with a period of 11 years and a maximum separation of 0″.05. More recently,

Finder Chart



156. RMK 26 PAV = WDS J20516−6226

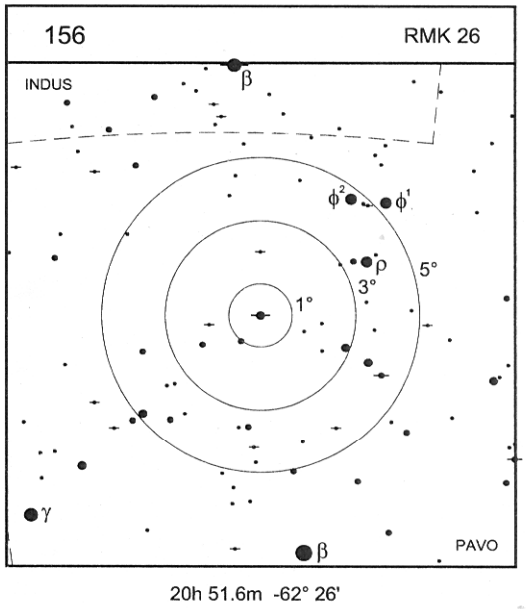
Table 9.156 Physical parameters for RMK 26 Pav — ADD

RMK 26	RA: 20 51 38.47	Dec: −62 25 45.6	WDS: 1322(64)	
V magnitudes	A: 6.27	B: 6.44		
$(B-V)$ magnitudes	A: +0.22	B: +0.29		
μ(A)	82.70 mas yr^{-1}	± 0.50	−46.56 mas yr^{-1}	± 0.07 (DR2)
μ(B)	82.08 mas yr^{-1}	± 0.06	−42.34 mas yr^{-1}	± 0.08 (DR2)
π(A)	13.51 mas	± 0.05	241 light yr	± 1 (DR2)
π(B)	13.53 mas	± 0.06	241 light yr	± 1 (DR2)
Spectra	A: A2III	B: A3III		
Luminosities ($L_\odot$)	A: 14	B: 12		
Catalogues (A/B)	HR 7959/60	HD 198160/1	SAO 254883/4	HIP 102962
DS catalogues	RMK 26			
Radial velocity (A/B)	−16.00 km s^{-1}	± 7.4	−10 km s^{-1}	± 5
Galactic coordinates	333°.318	−37.624		

History

This pair was found by Rümker in 1826. Christian Carl Ludwig Rümker [607] was born at Stargard, Meklinburg-Strelitz, the son of a court councillor [607]. Having trained as a builder he was more interested in mathematics and taught the subject for two years in Hamburg. He came to England in 1809 and having been press-ganged into the Navy in 1813 he subsequently taught cadets on three Royal Navy ships. Whilst in the Mediterranean he met Franz Xavier von Zach, who induced him to pursue astronomy. He left the Navy in 1814 and became private astronomer to Sir Thomas Brisbane, who was was appointed Governor of Australia, and on arrival Brisbane set up a private observatory at Parramatta, which Rümker used. Rümker's relations with Brisbane were fractious on occasion and he left Parramatta, only to return in 1826 on the appointment of a new Governor. He started the observations which led to his small catalogue of bright and

Finder Chart



158. 61 CYG = STF 2758 = WDS J21069+3845AB

Delete 2

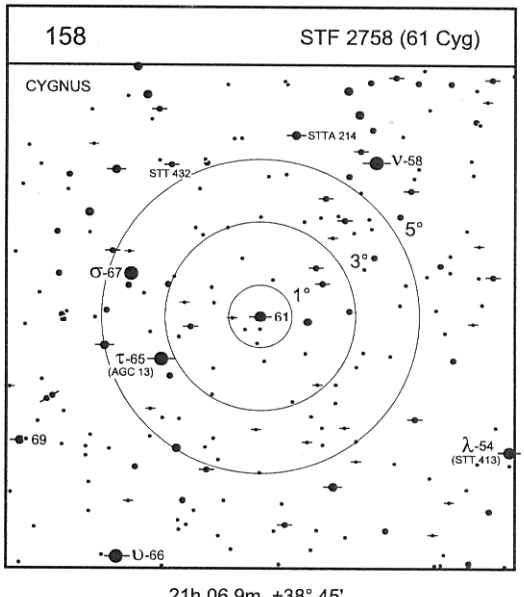
Table 9.158 Physical parameters for 61 Cyg

STF 2758	RA: 21 06 53.952	Dec: +38 44 57.9	WDS 1(1711)		
V magnitudes	A: 5.20	B: 6.05			
$(B-V)$ magnitudes	A: +1.27	B: +1.54			
μ(A)	4164.17 mas yr^{-1}	± 0.19	3249.99 mas yr^{-1}	± 0.25 (DR2)	
μ(B)	4105.79 mas yr^{-1}	± 0.09	3155.76 mas yr^{-1}	± 0.10 (DR2)	
π(A)	286.15 mas	± 0.06	11.398 light yr	± 0.002 (DR2)	
π(B)	285.95 mas	± 0.10	11.406 light yr	± 0.004 (DR2)	
Spectra	A: K5V	B: K7V			
Masses ($M_\odot$)	A: 0.70		B: 0.63		
Radii ($R_\odot$)	A: 0.665	± 0.005	B: 0.595	± 0.008	
Luminosities ($L_\odot$)	A: 0.08	B: 0.04			
Catalogues (A/B)	61 Cyg	HR 8085/6	HD 201091/2	SAO 70919	HIP 104214/7
DS catalogues	Mayer 70	H 4 18	STF 2758	BDS 10732	ADS 14636
Radial velocity (A/B)	−65.74 km s^{-1}	± 0.09	−64.07 km s^{-1}	± 0.08	
Galactic coordinates	82°.320	−5°.818			

History

R. G. Aitken *op. cit.* noted that Bradley had been the first to observe both components, in 1753, and quoted the relative positions of the stars as noted by John Herschel. Mayer included 61 Cyg in his catalogue and the pair came to the attention of Sir William Herschel on 20 September 1780. He recorded: 'Pretty unequal. L(arge). pale r(ed).; s(mall) r.; or L(arge). r(ed).; s(mall). garnet'. About a decade later Piazzi observed them and when he compared his positions with those of Bradley, 40 years earlier, he noted the significant differences and as a result called 61 Cygni 'The flying star'. In 1838, F. W. Bessel [612] announced that his researches using the Konigsberg heliometer had indicated that 61 Cygni had a measurable parallax and the value was 0″.3136, the first time that the distance to a star had been geometrically determined and preceding similar work on α Centauri, by Henderson, by a few months. Bessel's value is remarkably accurate;

Finder Chart



REPLACE FINDER CHART

159. H 1 48 CEP = WDS J21137+6424

ADD 21 13 42.48 +64 24 14.3

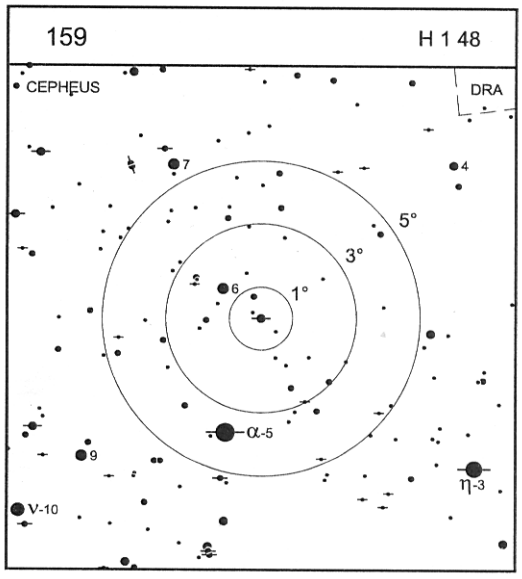
Table 9.159 Physical parameters for H 1 48 Cep

H 1 48	RA: 06 54 38.63	Dec: +13 10 40.1	WDS: 387(148)	
V magnitudes	A: 7.21	B: 7.33		
$(B-V)$ magnitudes	A: +0.77			
μ	+16.89 mas yr^{-1}	±0.51	−105.13 mas yr^{-1}	± 0.43
π	23.39 mas	± 0.42	42.8 light yr	± 0.8
Spectra	G2IV	G2IV		
Luminosities ($L_\odot$)	A: 2	B: 1.8		
Catalogues	HR 8133	HD 202582	SAO 19257	HIP 104788
DS catalogues	H 1 48	AC 19	BDS 10863	ADS 14783
Radial velocity	30.30 km s^{-1}	± 0.2 km s^{-1}		
Galactic coordinates	101°.969	+10°.812		

History

Sir William Herschel called it 'A minute and beautiful double star' in his log of 27 September 1782. He goes on to say 'A little unequal. Both pr (pink-rose colour). Almost in contact with 460, with 625 better divided with 657 still better'. After that the star appears to have been completely ignored by observers. It closed up to below 0″.5 in 1825 and remained below that value until the late 1840s. In 1859 Alvan Clark rediscovered it when it was separated by 0″.9. It was subsequently noted to be a known pair but even in Burnham's General Catalogue it was dismissed with the phrase 'change doubtful'. Burnham did concede that 'the later measures appear to show a little direct motion'. In the period 1910–1920 the star underwent another unobserved close approach and Philip Fox measured it in 1925 at a separation of 0″.5. In 1932, Robert Aitken, in his General Catalogue commented that 'A complete set of measures of this pair is greatly to be desired'. In fact it would be almost another century before a representative orbit would be calculated.

Finder Chart



160. τ CYG = AGC 13 = WDS J21148+3803 AB

ADD

Table 9.160 Physical parameters for τ Cyg

AGC 13	RA: 21 14 47.49	Dec: +38 02 43.1	WDS ranking: 93(346)		
V magnitudes	A: 3.87	B: 6.65	F: 11.95	I: 16.02	
$(B-V)$ magnitudes	A: +0.41	B: +0.83			
μ	+196.99 mas yr^{-1}	±0.30	+410.28 mas yr^{-1}	± 0.30	
π	49.16 mas	± 0.40	65.9 light yr	± 0.5	
μ(A)	136.61 mas yr^{-1}	± 0.71	451.92 mas yr^{-1}	± 0.80 (DR2)	
π(A)	49.58 mas	± 0.46	65.8 light yr	± 0.6 (DR2)	
Spectra	F3V	F7V			
Masses ($M_\odot$)	A: 1.0	B: 0.75			
Luminosities ($L_\odot$)	A: 9	B: 0.7			
Catalogues	65 Cyg	HR 8130	HD 202444	SAO 71121	HIP 104887
DS catalogues	AGC13 (AB)	BDS 10846	ADS 14787	JOD 20 (FaFb)	
Radial velocity	−20.90 km s^{-1}	± 0.8			
Galactic coordinates	82°.854	−7°.432			

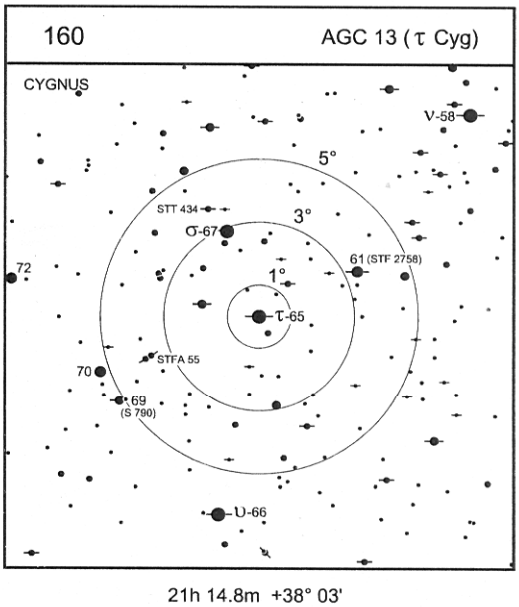
History

The star was first resolved by Alvan G. Clark, who was testing a 26-inch objective bound for the McCormick Observatory in October 1874. It was first measured during the same year by Simon Newcomb [622] using the 26.5-inch refractor at Washington. In 1908, spectrograms of τ Cyg taken by Barrett [616] showed that the star had a variable radial velocity and a period of only 3.5 hours, a record at the time. In 1921 Parasképvopoulos [621] found a radial velocity variation with a period of 0.1425 days but also argued that it could be due to radial pulsation.

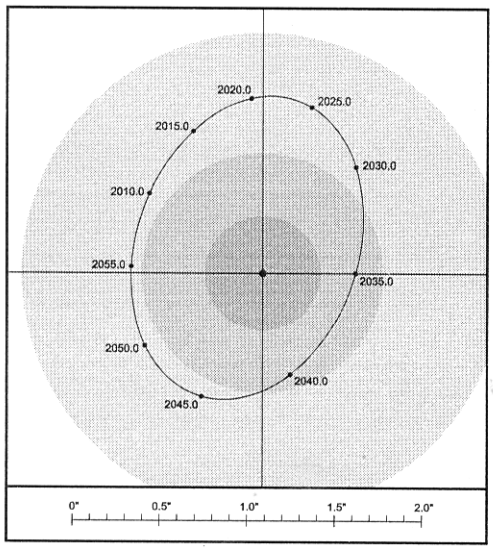
The Modern Era

In 1960 Abt [617] re-observed τ Cyg spectroscopically and found no sign of a variation in radial velocity. He also argued that combining a period of 0.143 days with a parallax of 0″.47

Finder Chart



Orbit



Ephemeris for AGC 13 AB (2018 to 2036)

Orbit by Mut (2010e) Period: 49.6257 years, Grade: 1

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2018.0	192.1	0.98	2028.0	150.1	0.91
2020.0	183.8	1.01	2030.0	138.9	0.81
2022.0	175.8	1.02	2032.0	124.4	0.69
2024.0	167.8	1.01	2034.0	103.7	0.58
2026.0	159.4	0.97	2036.0	74.6	0.50

would yield a rotational velocity at the equator of 750 km s^{-1}, which is not viable. Heintz [618], ten years later, also dismissed the idea that the 0.143-day period could be due to a close companion of the primary star. A number of independent reports indicated that photometrically τ Cyg was shown to be variable with an amplitude of about 0.02 magnitudes, but the most recent observations, by Bartolini & Dapergolas [619] in 1980, indicate no period. The best interpretation of the radial velocity and light variations is that the star is a bright member of the δ Scuti class of pulsating variables. The WDS catalogue lists a number of faint stars within 10 arcminutes of the A component but only two of them (F and I) share the same considerable proper motion. Imaging of star F with the 2.2-metre reflector at Almeria, Spain, by Jodar *et al.* [623] showed that F is a close pair with a slightly fainter companion 0″.4 distant in PA 18°.

Exoplanet Host?

The most recent observational investigation of τ Cyg was done by Muterspaugh *et al.* [620], who used the extremely precise ground-based NPOI interferometer to yield an orbit with a period of 49.626 years. They speculated on the existence of a substellar companion (possibly having a period of 810 days) but suggested that this needed confirmation.

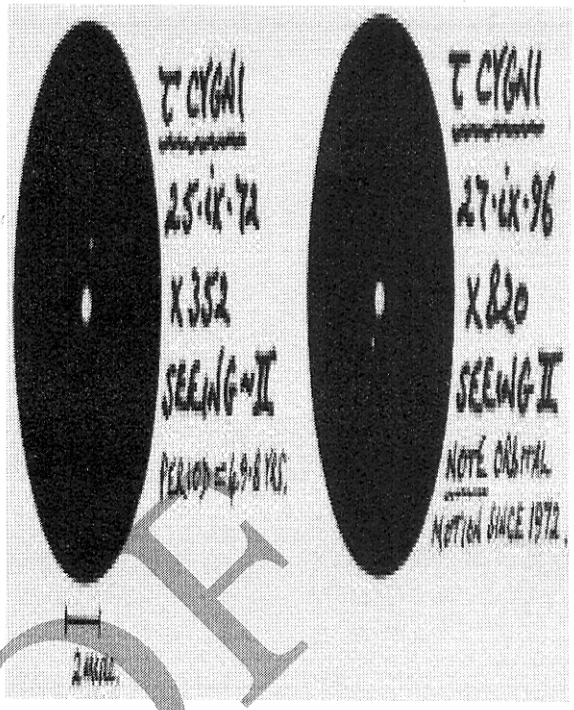


Figure 9.4 τ Cygni, observed with 12.5-inch Calver reflector in 1972 (left) and 1996 (right) showing orbital motion over almost half an orbital period (49 years) (C. Taylor)

Observing and Neighbourhood

The ephemeris shows that for the next ten years or so the stars are near the widest separation that they can achieve. A 20-cm aperture certainly will resolve them and a good 15-cm should also show them clearly. This system is one of the few in which orbital motion can be seen over a few years. Christopher Taylor, who operates a 12.5-inch Calver reflector in Oxfordshire, has made drawings of a number of bright binaries and his observations of τ Cyg, shown below, clearly show the stars on opposite sides of their apparent orbit. Close to τ (1°.6 NW) is the famous nearby binary 61 Cygni. The binocular pair STFA 55 (6.6, 6.6, 304°, 364″) is 2°.0 ESE of τ. For the telescopic observer there are four faint stars between magnitudes 11 and 14 in the field; S 790 (= 69 Cyg, 5.9, 10.2, 99°, 53″, 2012, and another 11.7 at 34″, 2012) is 1°.0 SSE of STFA 55. Marcel Fay adds a maguitude 13.9 (FYM 124) at 19″, 84° from C (2014). Two degrees N and slightly E is STT 434 (6.7, 9.9, 122°, 24″, 2006). A third star (maguitude 11) is at 316°, 98″.

Measures

Early measure (HAL)	160°.2	1″.04	1876.90
(Orbit	160°.9	0″.98)	
Recent measure (RAO)	213°.4	0″.86	2013.62
(Orbit	213°.0	0″.88)	

161. θ IND = HJ 5258 = WDS J21199–5327

HJ 5258 = Delete 'j' Correct to '19'

Table 9.161 Physical parameters for θ Ind

HJ 5458	RA: 21 14 51.89	Dec: −53 26 57.4	WDS: 986(78)	
V magnitudes	A: 4.50	B: 6.93		
$(B-V)$ magnitudes	A: +0.18	B:		
μ(A)	106.23 mas yr^{-1}	± 0.54	−67.03 mas yr^{-1}	± 0.45 (DR2)
μ(B)	92.93 mas yr^{-1}	± 0.77	−76.52 mas yr^{-1}	± 0.06 (DR2)
π(A)	33.93 mas	± 0.27	96.1 light yr	± 0.8 (DR2)
π(B)	33.46 mas	± 0.04	97.5 light yr	± 0.1 (DR2)
Spectra	A: A5IV-V	B: G0V		
Luminosities ($L_\odot$)	A: 11	B: 1		
Catalogues (A/B)	HR 8140	HD 202730	SAO 246965/4	HIP 105319
DS catalogues	HJ 5258 (AB)	MRN 3 (AaAb)		
Radial velocity	−14.5 km s^{-1}	± 2		
Radial velocity (B)	−6.49 km s^{-1}	± 0.16		(DR2)
Galactic coordinates	343°.686	−43.320		

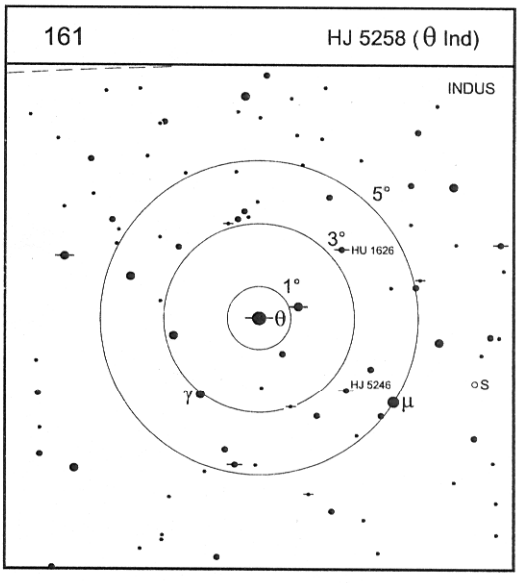
History

This pair was found by John Herschel on 8 July 1834. He notes it as 'beautiful' in the section marked 'Reduced observations of double stars' in the 1847 catalogue. However, on three subsequent nights out of four in which he made micrometric measures, he noted the magnitudes of A and B to be 5 and 10 and says that in less than ideal conditions the companion could be 'difficult'. The modern visual magnitude for B is 6.9.

The Modern Era

The primary is a fast-rotating star with equatorial rotational velocity measured at 210 km s^{-1}. As a relatively nearby star it has been examined [624] for the presence of exo-zodiacal dust using an infrared photometer fitted to the four outrigger telescopes of the VLT, giving high-resolution information

Finder Chart



162. β CEP = STF 2806 = WDS J21287+7034AB

Table 9.162 Physical parameters for β Cep

STF 2806	RA: 21 28 39.597	Dec: +70 33 38.57	WDS: 668(102)		
V magnitudes	Aab: 3.17	B: 8.63			
$(B-V)$ magnitudes	A: −0.23	B: -			
μ(A)	14.77 mas yr^{-1}	± 1.66	7.94 mas yr^{-1}	± 1.75 (DR2)	
μ(B)	9.98 mas yr^{-1}	± 0.06	6.67 mas yr^{-1}	± 0.06 (DR2)	
π(A)	9.67 mas	± 0.99	337 light yr	± 35(DR2)	
π(B)	4.72 mas	± 0.03	691 light yr	± 4 (DR2)	
Spectra	Aa: B2III+?	B: A1V			
Masses ($M_\odot$)	Aab: 12	± 1.0			
Radii ($R_\odot$)	Aab: 6.5	± 1.2			
Luminosities ($L_\odot$)	A: 460	B: 13			
Catalogues	8 Cep	HR 8238	HD 205021	SAO 10057	HIP 106032
DS catalogues	H 3 6 (AB)	STF 2806 (AB)	BDS 11046	ADS 15032	LAB 6 (Aa)
Radial velocity	−8.2 km s^{-1}	± 2			
Galactic coordinates	107°.539	+14°.026			

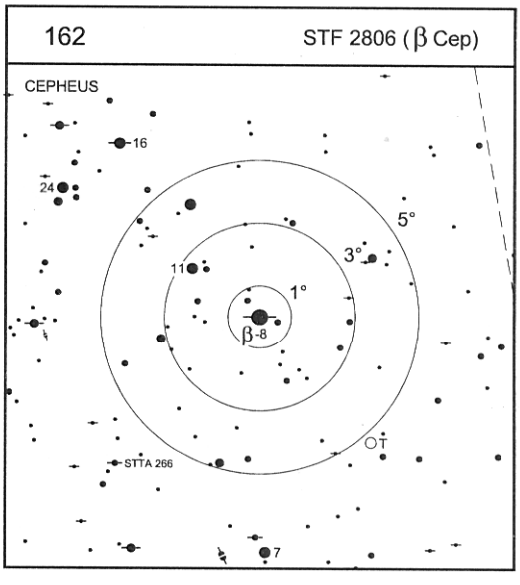
History

William Herschel observed β Cep on 31 August 1779, with the following notes 'Double. Very unequal. L(arge). blueish w(hite).; S(mall). garnet. Distance 13″.125, Position 15° 28′ preceding'. Smyth found the stars white and blue and noted that the pair had been seen by Piazzi, who estimated the companion at maguitude 11. F. G. W. Struve notes greenish-white and blue whilst, more recently, Sissy Haas records a colour of green for the secondary in 60-mm aperture at ×25.

The Modern Era

The pioneer of speckle interferometry, Antoine Labeyrie, first discovered [628] the duplicity of the bright star during observations to measure stellar diameters made with the 200-inch (508 cm) reflector on Palomar Mountain in 1971. Subsequently Paul Couteau tried to resolve the star visually using

Finder Chart



REPLACE FINDER CHART

the large refractors in the south of France but was unable to do so, confirming that the difference in magnitude was at least 3 in *V*. The pair β Cep has a magnetic field that might be responsible for the spherical shell or ring-like structure found around the star [630] whilst high-resolution data taken with the VEGA instrument on the CHARA long baseline array was being analysed.

Observing and Neighbourhood

The Aa system has a period of 83 years and is very highly inclined to the line of sight, so that it is possible that an eclipse might take place close to the next periastron in the 2060s. The separation is currently near its maximum of 0″.3 and will reduce to under 0″.01 in 2076. It now seems clear from the DR2 results that the Struve component is not physical. Four degrees E is STF 2883 (5.6, 8.6, 253°, 14″.2, 2016) whilst 3° SE is a pair marked STTA 266 on *CDSA2* but which is neither STTA 266 nor STT 266.

Measures

Early measure (STF)	250°.0	13″.57	1832.26
Recent measure (FYM)	248°.3	14″.1	2013.74

Should be STTA 226

(Bob, I have corrected it on the chart)

165. 53 AQR = SHJ 345 = WDS J22261−1645AB

Correct to '6'

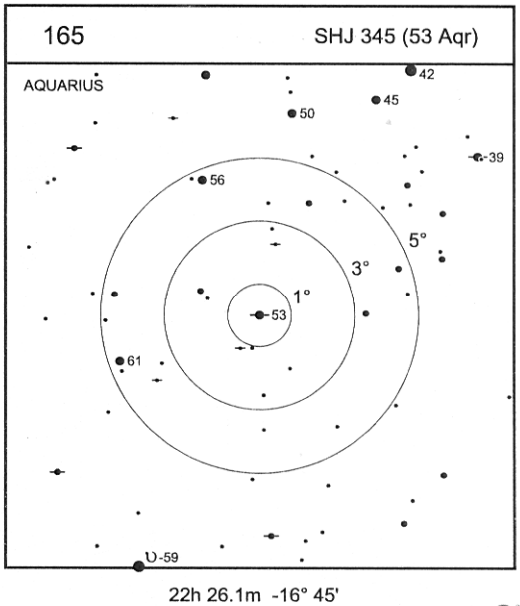
Table 9.165 Physical parameters for 53 Aqr

SHJ 345	RA: 22 26 34.30	Dec: −16 44 31.9	WDS: 163(250)	
V magnitudes	A: 6.24	B: 6.39		
$(B-V)$ magnitudes	A: +0.68	B: +0.70		
μ	A: 200.59 mas yr^{-1}	± 1.76	B: −14.51 mas yr^{-1}	± 0.89
π	49.50 mas	± 1.23 mas	66 light yr	± 2
μ(A)	254.95 mas yr^{-1}	± 0.43	−62.14 mas yr^{-1}	± 0.21 (DR2)
π(A)	51.51 mas	± 0.13	63.3 light yr	± 0.2 (DR2)
Spectra	A: G2V	B: G3V + ?		
Masses ($M_\odot$)	A: 1.06	B: 1.03		
Radii ($R_\odot$)	A: 1.02	B: 0.98		
Luminosities ($L_\odot$)	A: 1.1	B: 0.9		
Catalogues (A/B)	HR 8545/4	HD 212698/7	SAO 165078/7	HIP 110778
DS catalogues	SHJ 345	BDS 11715	ADS 15934	
Radial velocity	2.28 km s^{-1}	± 0.15		
Galactic coordinates	42°.553	−54°.980		

History

Herschel first noted the duplicity of 53 Aqr on a cloudy night (20 September 1786). He revisited the system on 6 September 1793 and found the stars to be in the second or third class of separation, rather nearer the latter, so one might assume from this a separation of about 10″. Not long afterwards Piazzi also noted both components and in his catalogue of 1814 gives the differences in RA of 12″.7 and in declination of 4″.3, which yield a position angle 288° and a separation of 13″.4 for the epoch 1800. Both stars were assigned the magnitude 6.7. In 1901 Burnham noted star C of maguitude 12.8 at a distance of 46″.7 and PA 339° and used this to check on the proper motions of both components; because of their mutually large size and direction, this led him to classify 53 Aqr as being in the 61 Cygni class of binary stars. He later found D, at magnitude 13.8, just 1″.8 from C but this has only ever been measured twice and there is not enough data

Finder Chart



REPLACE FINDER CHART

166. KRÜGER 60 CEP = WDS J22280+5742 AB

Add Cep

Delete 3'

Delete 3'

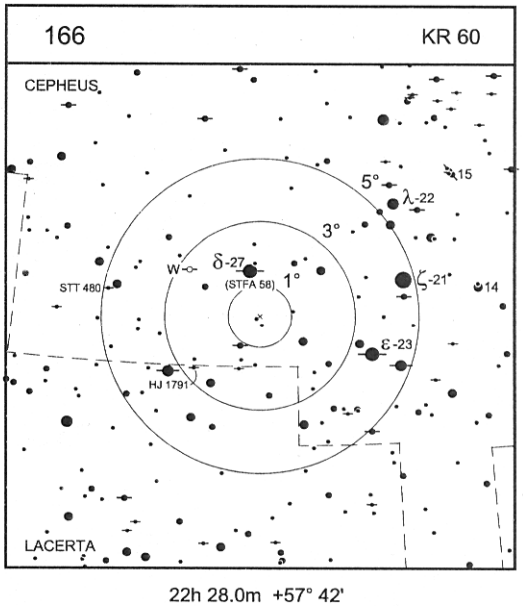
Table 9.166 Physical parameters for KR 60

KR 60	RA: 22 27 59.473	Dec: +57 41 45.23	WDS ranking: 125(289)	
V magnitudes	A: 9.93	B: 11.41		
$(B-V)$ magnitudes	A: +0.41	B: +2.2		
μ(A)	-725.23 mas yr^{-1}	$\pm$ 0.54	-223.46 mas yr^{-1}	$\pm$ 0.35 (DR2)
μ(B)	-934.10 mas yr^{-1}	$\pm$ 1.32	-686.24 mas yr^{-1}	$\pm$ 1.41 (DR2)
π(A)	249.39 mas	$\pm$ 0.17	13.078 light yr	$\pm$ 0.009 (DR2)
π(B)	249.97 mas	$\pm$ 0.24	13.048 light yr	$\pm$ 0.012 (DR2)
Spectra	A = M2.0V	B = M4.0V		
Masses ($M_\odot$)	A: 0.271		B: 0.176	
Radii ($R_\odot$)	A: 0.35		B: 0.24	
Luminosities ($L_\odot$)	A: 0.001	B: 0.0004		
Catalogues (A/B)	DO Cep	HD 239960	HIP 110893	
DS catalogues (AB)	BDS 11761	ADS 15972		
Radial velocity	-33.94 km s^{-1}	$\pm$ 0.1		
Galactic coordinates	104°.687	-0°.003		

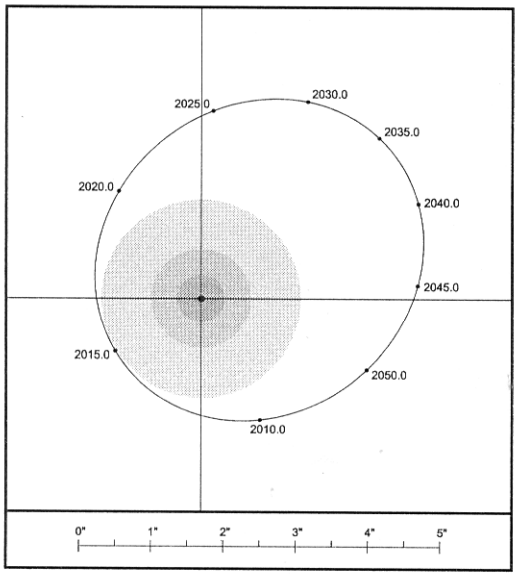
History

The star is named after A. Krüger [643] at Helsinki, who noticed, on plates taken for the Astronomische Gesellschaft for the Helsingfors/Gotha zone, that there was a fainter star (C) 12″ away from the ninth magnitude primary. In 1890, Burnham [644] observed this system and noted that there was a closer companion (B) about 2″.3 distant, nearly due S. In 1898, when it was next observed, by Doolittle [645], 'a very decided change had taken place…' and it was subsequently followed with interest, particularly by Barnard [642], who observed it annually from 1903 until the year of his death (1921) and measured it on 28 nights in 1916.

Finder Chart



Orbit



Ephemeris for KR 60 AB (2018 to 2036)

Orbit by Hei (1986b) Period: 44.67 years, Grade: 2

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2018.0	244.5	1.60	2028.0	160.6	2.94
2020.0	217.2	1.89	2030.0	151.7	3.10
2022.0	197.6	2.20	2032.0	143.6	3.22
2024.0	182.7	2.48	2034.0	136.0	3.30
2026.0	170.7	2.73	2036.0	128.6	3.34

The Modern Era

Starting in 1931, observers at Sproul Observatory took a long series of plates with the intention of obtaining a visual orbit and mass sum for the two components. In a short note to PASP in 1951, P. van de Kamp & Lippincott [646] noted that on one occasion in 1939 the two stars, normally 1.5 magnitudes apart in the visual band, appeared to be equally bright and concluded that star B was a flare star, one of only six known at the time. The component KR 60 has been surveyed a number of times in the last decade in an attempt to find sub-stellar companions or exoplanets. Heinze *et al.* [648] found an object of $K = 16$ some 7″ from A (which is 4.7 in the same infrared band), but it turned out to be a background object. The WDS catalogue contains 16 companions to A, from magnitudes 8 to 16, all of which, with the exception of B, are background objects whose positions with respect to AB are changing rapidly owing to the large proper motion of the binary. The trigonometric parallax found by Hipparcos is not as precisely defined as some single stars observed by the satellite, because of the proximity of the fainter star, but, at a distance of 13 light years, KR 60 is one of the most nearby stars. It is also getting nearer to the Solar System and will approaches to within 6.3 light years in around 89,000 years' time.

Delete

Observing and Neighbourhood

One of the more difficult pairs to observe, because of the faintness and closeness of the stars, this object is nevertheless worth the attempt to see, providing you have 30-cm. It is certainly beyond the range of the 8-inch at Cambridge at the present time, although Robert Burnham suggested that a good 6-inch (15-cm) at high power will suffice to show the pair (which was separated by 2″ when he made his comments in 1976. His *Celestial Handbook*, Volume 2, p. 601, shows the flare in star B captured at Sproul in 1939. Having reached periastron in 2015, the stars are now separating and the annual angular motion is between 10° and 15° for the near future, so even without a measuring device the movement in position angle ought to be obvious. The system KR 60 is close to δ Cephei (p. xx), being about 45′ S and is shown in the finder chart. There is a comprehensive paper on this star by Wilfried Knapp and John Nanson, which is freely available in JDSO [649]. *CDSA2* shows two stars within 2° or so. One point five degrees ESE is HJ 1791 (7.7, 9.7, 59°, 17″, 2016). The galactic cluster NGC 7790 is 2° E and on the SW edge is STT 480 (7.7, 8.6, 116°, 30″.7, 2016).

NGC 7380

Measures

Early measure (BU)	126°.5	3″.36	1902.81
(Orbit	126°.0	3″.34)	
Recent measure (WSI)	326°.1	1″.47	2013.73
(Orbit	327°.7	1″.44)	

430

168. δ CEP = STFA 58 = WDS J22292+5825AB

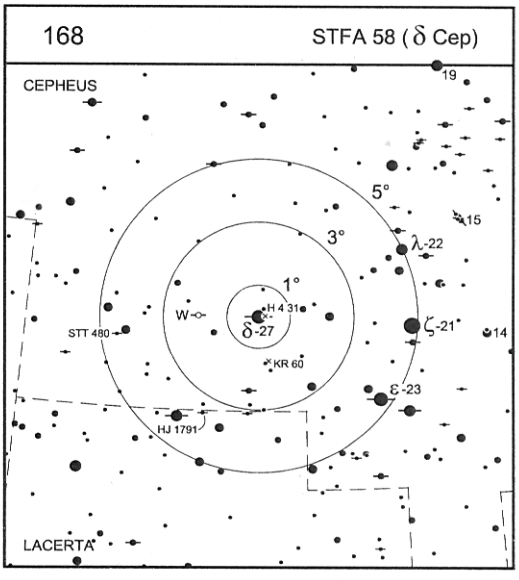
Table 9.168 Physical parameters for δ Cep

STFA 58	RA: 22 29 10.25	Dec: +58 24 54.7	WDS: 789(91)		
V magnitudes	Aab: 4.21v	B: 13.0	Cab: 6.11		
$(B-V)$ magnitudes	A: +0.89	C: +0.07			
μ(A)	15.35 mas yr^{-1}	± 0.22	3.52 mas yr^{-1}	± 0.18	
μ(B)	16.19 mas yr^{-1}	± 0.59	4.28 mas yr^{-1}	± 0.50	
π(A)	3.66 mas	± 0.15	891 light yr	± 37	
π(B)	3.65 mas	± 0.15	894 light yr	± 37	
μ(C)	14.10 mas yr^{-1}	± 0.09	3.93 mas yr^{-1}	± 0.09 (DR2)	
π(C)	3.36 mas	± 0.05	971 light yr	± 14 (DR2)	
Spectra	A: F5Iab+?	C: B7+F5V?			
Masses	Aab: 5.1 $M_\odot$		Cab: 4.0 $M_\odot$		
Luminosities ($L_\odot$)	Aab: 1290	Cab: 270			
Catalogues (A/C)	27 Cep	HD 213306/7	HR 8571(A)	HIP 110991/8	SAO 34508/6
DS catalogues	H 5 4 (AC)	STFA 58 (AC)	BU 702 (AB)	BDS 11772	ADS 15987
Radial velocity (A/B)	−24.00 km s^{-1}	± 0.2	−21.60 km s^{-1}	± 0.9	

History

Noted by William Herschel on 31 August 1779: 'Double. Considerably unequal. L(arge). reddish w(hite).; S(mall). blueish w.' The pair δ Cephei has been compared with Albireo with respect to the brightness and colours of the stars and the separation. Coincidentally, Herschel noted Albireo 13 days after he observed δ and catalogued it as H 5 5. The star δ Cephei is most noted for its regular brightness variability. In 1784, a talented young astronomer called John Goodricke [655] noticed δ and started to carry out a series of visual estimations of the star's brightness. In 1898, Burnham [678] found a 13th magnitude star 20″ away in PA 284°, which is now known as B. The astronomer Bélopolsky [657], using the 30-inch refractor at Pulkova in 1895, took spectra of δ Cep and announced that it was a spectroscopic binary with

Finder Chart



REPLACE FINDER CHART

a period of five days and nine hours. In 1914, however, Harlow Shapley [658] discussed the problems associated with linking the observed radial velocity variations with binarity. He argued that the shape of the curve was non-Keplerian, there was never a secondary spectrum visible, and the gradual change of spectral type with time could not be argued by the presence of two stars. He proposed that the variations in radial velocity were due to the pulsation of the star's outer layers rather than the presence of a companion star. In 1912 Leavitt & Pickering [659] found that the luminosity of a Cepheid was directly proportional to its period of pulsation, and this can be used to form the basis of distance measurement in stellar astronomy. Unfortunately Cepheids are, on the whole, rare and distant objects and even the nearest one, Polaris, is about 430 light years away. Even using the Hipparcos satellite, the distance is only determined to an accuracy of about 4% for δ Cephei. The advent of Gaia promises a revolution in the definition of the distance scale, with hundreds of Cepheids becoming accessible. In the case of δ Cep, DR2 contains the astrometry only of the wide Herschel star, but it does appear to be at a very similar distance to the Cepheid.

The Modern Era

Marcel Fay [660] added four faint (13–15 magnitude) and distant companions to A, whilst Jim Daley [664] measured a 13.9 maguitude star at 109″, which has a close partner of maguitude 14.0 at 23° and 1″.4. The system was imaged by Benedict *et al.* [661] with the HST and they found that A and C have the same parallaxes (see above), which put the stars slightly further away than the Hipparcos result, π = 3.77 mas (865 light years). Star C is known to be a variable and also to be a binary. A preliminary period of 390 days was found from astrometry carried out with the HST in 2002. In 2015 Anderson *et al.* [662] published a paper in which they found that δ itself was also a spectroscopic binary, with a period of 2201 days. The new component was found with a high-resolution spectrograph, called Hermes, fitted to the Flemish 1.2-metre Mercator telescope on La Palma. Once the known pulsation period of the Cepheid was allowed for, the residuals showed the effect of the companion star, which they suggest is a young main sequence object. They derived a trigonometric parallax which puts δ Cephei at a distance of 778 light years. A subsequent search for this new companion using the CHARA array [663] in the infrared was unsuccessful.

Observing and Neighbourhood

The two bright stars form a splendid sight in a small telescope and show a colour contrast. Admiral Smyth recorded orange tint and fine blue, whilst John Nanson in 2010 found 'the primary is a rich yellow with a tinge of red to it and 'C' is pronounced blue leaning a bit towards white'. Move 20′ W and you'll reach the coarse triple star H 4 31 (8.5, 10.5, 4°.25″, and a maguitude 9.5 at 321°, 78″). About 45′ S is the nearby red dwarf binary Krueger 60. The object STF 2950, which is 4°.5 NE, is an orbital pair with period 804 years. The discovery separation was 3″ but the pair are now expected to be at 272°, 1″.1 in 2020. The stars are 6.1 and 7.1.

5·8′

Measures

Early measure (STF)	192°.0	40″.86	1835.15
Recent measure (WSI)	190°.9	40″.94	2013.55

170. STF2944 AQR = WDS J22478−0414AB,C

ADD

Table 9.170 Physical parameters for STF 2944 Aqr

STF 2944	RA: 22 47 50.19	Dec: −04 13 44.5	WDS: 75(405) (AB) WDS: 523(121) (AC)	
V magnitudes	A: 7.30	B: 7.68	C: 8.52	
$(B-V)$ magnitudes	A: +0.70	B: +0.75	C: +0.47	
μ(A)	−215.09 mas yr^{-1}	± 0.15	−313.43 mas yr^{-1}	± 0.12 (DR2)
μ(B)	−191.22 mas yr^{-1}	± 0.13	−300.45 mas yr^{-1}	± 0.11 (DR2)
μ(C)	6.25 mas yr^{-1}	± 0.42	−8.17 mas yr^{-1}	± 0.45 (DR2)
π(A)	30.11 mas	± 0.11	108.3 light yr	± 0.4 (DR2)
π(B)	29.91 mas	± 0.06	109.0 light yr	± 0.2 (DR2)
π(C)	9.16 mas	± 0.20	356 light yr	± 8 (DR2)
Spectra	A: G2V	B: G4	C: F0V	
Luminosities ($L_\odot$)	A: 1.0	B: 0.8	C: 4	
Catalogues (A/B/C)		HD 215812/—/3	SAO 146315/5/7	HIP 112559
DS catalogues	H 2 57	STF 2944	BDS 11968	ADS 16270
Radial velocity (A/B)	−16.70 km s^{-1}	± 0.1	−25 km s^{-1}	± 5
Galactic coordinates	65°.296	−52°.675		

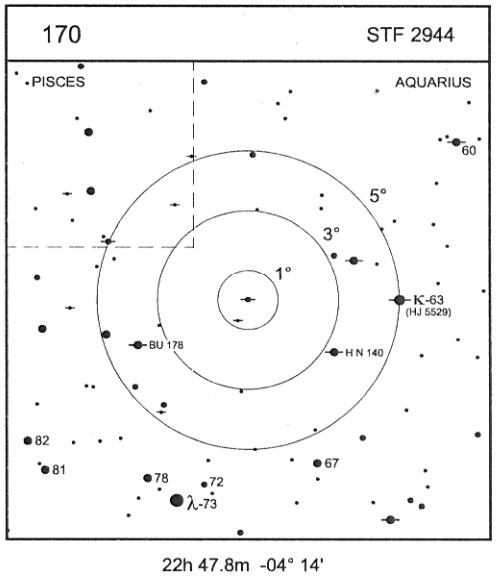
History

'Treble. About $2\frac{1}{2}$ degrees following κ, in a line parallel to α and η Aquarii.. Both r… With 460 $2\frac{1}{2}$ diameters of L(arger star).' So ran the report of William Herschel after his observation of 27 September 1782. Smyth notes 'yellowish, flushed white and flushed white'.

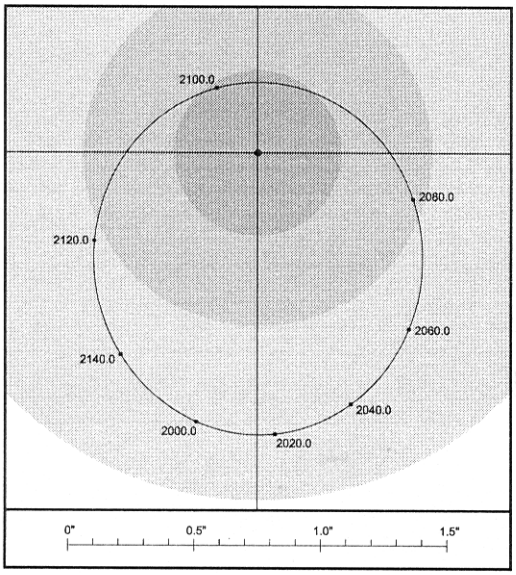
The Modern Era

Gaia has observed all three components. It confirms that the determined parallax of C shows that it is unassociated with AB. The linear ephemeris fits the observed positions of C with respect to A pretty well. The current orbit of AB is based on 60° of prograde motion around the apparent orbit although the separation has decreased from more than 4″ at discovery

Finder Chart



Orbit



Ephemeris for STT 489 AB (2016 to 2052)

Orbit by Sca (2009a) Period: 162.8 years, Grade: 3

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2016.0	0.3	1.12	2036.0	16.8	1.08
2020.0	3.5	1.12	2040.0	20.3	1.06
2024.0	6.8	1.11	2044.0	23.9	1.04
2028.0	10.0	1.11	2048.0	27.7	1.02
2032.0	13.4	1.10	2052.0	31.7	0.99

as single leading to some speculation that the B component may be variable.

The Modern Era

The large mass function derived from the spectroscopic orbit drew some attention from investigators, as they thought this suggested that the unseen spectroscopic companion was rather massive for an object which did not show up in the spectra. Trimble & Thorne [674], who were on the look-out for collapsed stars or neutron stars, had it on a list of SB1s with large mass functions. Gatewood *et al.* [675] used a series of Allegheny Observatory photographic plates of π Cep from 1925, extending about 80 years, to look at the astrometric history of the system. They found a 'wobble' with a period of 1.524 years, which coincided with the period of the spectroscopic binary AaAb. This most probably explains why the DR2 parallax barely improves on the Hipparcos value and will require further processing.

Observing and Neighbourhood

Smyth noted colours of deep yellow and purple for the two stars. The Pulkova pair is now at widest separation and the stars were seen just separated by Bart Fried [676] in New York State in early October 2017 using a 115-mm f/15 Brashear refractor at ×429. The right-hand star at the apex of the pentangle that forms the main shape of Cepheus is γ Cephei;. π can be found 3° S preceding. The John Herschel component C is currently 244° and 58″ from A and appears to moved changed little since discovery. About 10° away is β Cephei, the next star around the pentangle in a clockwise fashion (see p. xx). There are two STF pairs in the field, both of which need at least 15-cm owing to their faintness and closeness: STF 2963 (8.0, 8.5, 3°, 1″.9, 2016) is 1°.5 NNW of π whilst STF 3017 (7.6, 8.5, 19°, 1″.2, 2003) is 1°.5 SE. This pair has closed in from 2″.8 at discovery. A third star of maguitude 13.8 is at 145°, 88″, 2003.

replace with 'have'

Measures

Early measure (STT)	350°.1	1″.16	1846.48
(Orbit	355°.7	1″.12)	
Recent measure (DRU)	355°.3	1″.11	2010.68
(Orbit	356°.0	1″.12)	

418

175. STF 3050 AND = WDS J23595+3343AB

Table 9.175 Physical parameters for STF 3050 And (ADD)

STF 3050	RA: 23 59 29.33	Dec: +33 43 26.9	WDS: 62(433)		
V magnitudes	A: 6.46	B: 6.72			
$(B-V)$ magnitudes	A: +0.56	B: +0.59			
μ(A)	-62.46 mas yr^{-1}	$\pm$ 0.06	-109.74 mas yr^{-1}	$\pm$ 0.04 (DR2)	
μ(B)	-47.49 mas yr^{-1}	$\pm$ 0.06	-78.63 mas yr^{-1}	$\pm$ 0.04 (DR2)	
π(A)	33.71 mas	$\pm$ 0.04	96.8 light yr	$\pm$ 0.1 (DR2)	
π(B)	33.92 mas	$\pm$ 0.04	96.2 light yr	$\pm$ 0.1 (DR2)	
Spectra	A: F8V	B:			
Luminosities ($L_\odot$)	A: 1.8	B: 1.4			
Catalogues	37 And	HR 9074	HD 224635	SAO 73656	HIP 118281
DS catalogues	Mayer 80	H N 58	STF 3050	BDS 12675	ADS 17149
Radial velocity	-7.90 km s^{-1}	$\pm$ 0.2			
Galactic coordinates	110°.720	$-27°.913$			

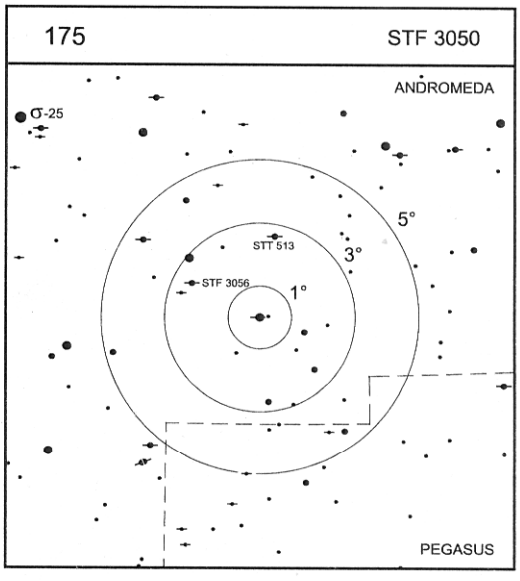
History

This star was found to be double by Christian Mayer in 1777 and later swept up by William Herschel in his double star survey in 1792 and announced as H N 58. Thomas Lewis notes in his 1906 volume that, as an easy pair, the measured separations should not have been quite so scattered, and he mentioned that one of the stars might be double. The mean positions plotted on his apparent orbit chart do show a sinusoidal variation with a possible period of 60 years, but no modern confirmation of higher multiplicity has been forthcoming. Lewis was convinced that the star was a binary but Burnham in his catalogue said 'apparently rectilinear motion', a view that pervaded the entry for the star in Espin's 1917 revision of *Celestial Objects for Common Telescopes.*

The Modern Era

The current orbit, whilst only graded 4, does a good job of representing the observed motion over the last 180 years

Finder Chart



Bob, Is this the 'observers Key' on Page 450

APPENDIX

Double Star Nomenclature

The normally accepted nomenclature for a double star is its WDS name, typically WDS J00003+1430 where the J denotes Julian and the standard epoch and equinox of 2000 defines the position. Many observers prefer to refer to stars by the original discoverer's names and numbers, as given in the WDS. Note that this may not necessarily refer to the astronomer who first found the star. Many of William Herschel's discovery names have been replaced by others – most notably the STF designation of F. G. W. Struve, who in 1827 produced the results of the first systematic search for new double stars in the Dorpat catalogue.

Below is a list of the most common abbreviations. The original nomenclature for some astronomers such as F. G. W. Struve, Burnham, or Finsen was originally a greek letter, i.e. Σ, β, or ϕ. These have now been romanized into STF, BU, and FIN. The table below is not comprehensive but does cover all the discovery designations to be found in this volume. A full list can be found on the USNO website `http:ad.usno.mil/wds`.

William Herschel's Double Star Classes

When Herschel published his first list of double star discoveries in 1782 he used a system of classification which allocated a class type to a particular range of angular separations. The closest discoveries went into Class I and so on. His second list, in 1784, also used the same system whilst his last lists, in 1800 and 1822, just used the classification N for New.

Class	Range	Example
I	0″–2″*	H I 16 = η CrB = STF 1937
II	2″–5″%	H II 13 = μ Dra = STF 2130
III	5″–15″	H III 16 = γ Del = STF 2727
IV	15″–30″	H IV 17 = α CVn = STF 1692
V	30″–60″	H V 55 = ν Dra = STFA 35
VI	60″–120″	H VI 40 = γ Lep
N	all	H N 23 = STF 427

* Herschel noted 'requiring indeed a very superior telescope, the utmost clearness of air, etc.'

% Herschel noted 'those suitable for very delicate measures of the micrometer'.

Resolution as a Function of Aperture

This is a subject on which there is no definitive view, but there are a number of relationships which can act as a reasonable guide to the limit of double star separation that might be expected for a given aperture. If a telescope aperture is not large enough then no amount of magnification will make any difference. The star images need to be separated in the focal plane by the objective or primary mirror. The most well-known criterion is Dawe's simple, relation which is 4″.56/D (inches) or 11″.6/D (cm). Dawes [127] worked this out on the basis of many observations of double stars with a range of apertures D. It is a good guide, provided that the aperture is relatively small and the stars are about maguitude 6 and of similar brightness. Once one of these conditions is relaxed then the numerator in the equation starts to increase. In 1914, Thomas Lewis [2] repeated Dawes' work but for a much large range of aperture and separation, and he found for equally bright stars (typically mags 5.7 and 6.4) the relation was 4″.8/D (inches) whilst for equally faint stars (8.5 and 9.1), it increased to 8″.5/D (inches). R. G. Aitken [1] later discussed these figures and found that for the 36-inch Lick refractor he could do significantly better than Lewis – in the cases just mentioned, 4″.3/D (inches) and 6″.1/D (inches) respectively, no doubt due to his keen eyesight and the superior seeing. The theoretical relationship, worked out by Airy from the wave theory of light, is called the Rayleigh limit. It is slightly more pessimistic than Dawes and comes in at 4″.8/D (the value also depends on the wavelength of light, a factor which Dawes did not include). Modern telescopes working in the infrared have a slight advantage. All this assumes that the two disks are fully separated, i.e. in tangential contact. Once a double star is so close that the image appears like a figure '8' or an oval then the criteria are not reliable. From years of experience RWA is aware that the Cambridge 20-cm refractor gives separate star images at around 0″.6 separation. In 2005 RWA observed

Bob, which table?