

Double Star Measurements with a 12-inch Newtonian Telescope, Annual Report of 2021

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Abstract

This report shows the results on 393 double star measurements from 2021. In 291 cases they were discovered in late 19th and early 20th century by the British astronomer T.H.E.C. Espin. The main components have an average brightness of 10.2 magnitudes, the companions are on average 2 mag weaker. Therefore, there are only a few observations for many pairs. However, they can be easily observed with a 12 inch telescope. Also double stars next to the Espin targets were observed. A new double star with the coordinates 20 10 28.142 +36 43 28.07 could also be found.

1. Introduction

In 2021 393 double stars were measured. As in previous years, pairs with magnitude differences were of interest, so the observations from 2017 to 2019 were continued (Schlimmer, 2018, 2019, 2021). In the past, the Espin double stars (discovery code “ES”) have proven to be suitable here. For this purpose, the WDS catalog was filtered for Espin entries and the results were saved in a separate file. In opposite to other well-known double star discoverer the Espin doubles aren’t spread over an wide separation interval. The majority of them have separations between 2-10 arc seconds. The average difference in brightness of the pairs is 2 magnitudes. Figures 1 and 2 gives an overview of the 3193 Espin double stars in WDS catalog:

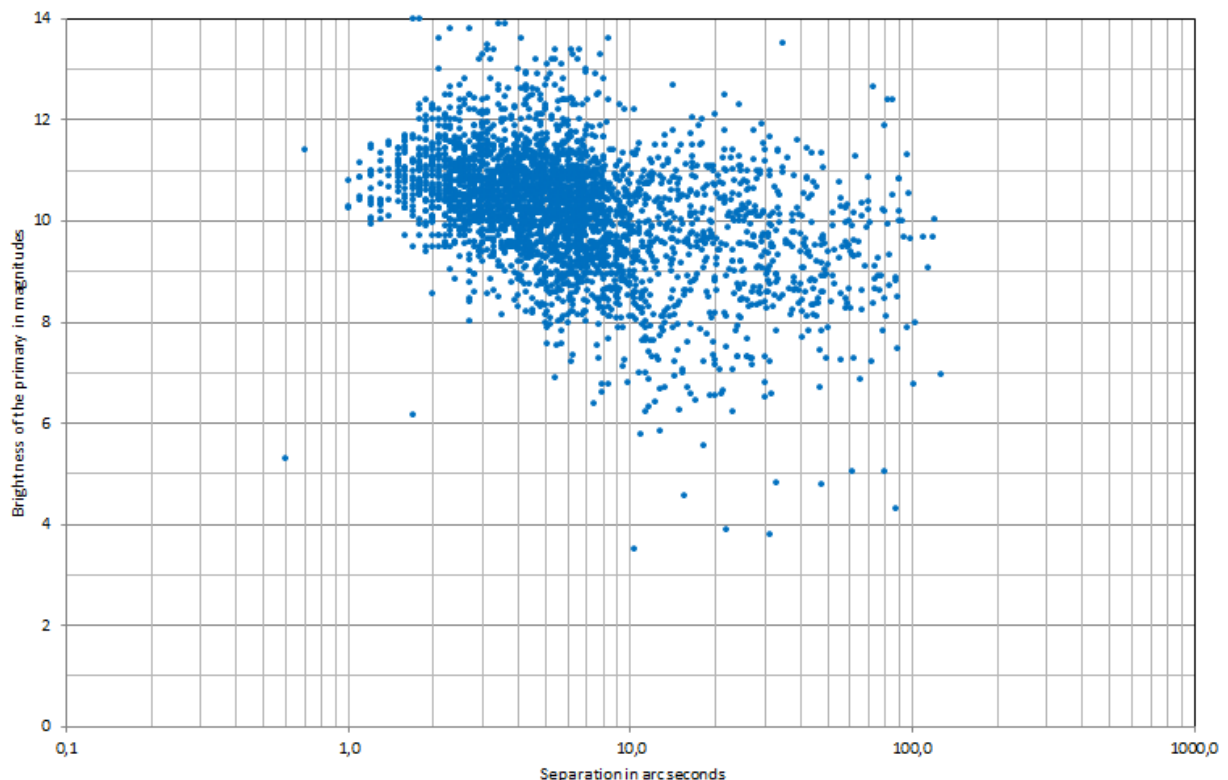


Figure 1: Distribution of the 3193 Espin double stars, brightness of the primary component over the separation (Schlimmer, 2020).

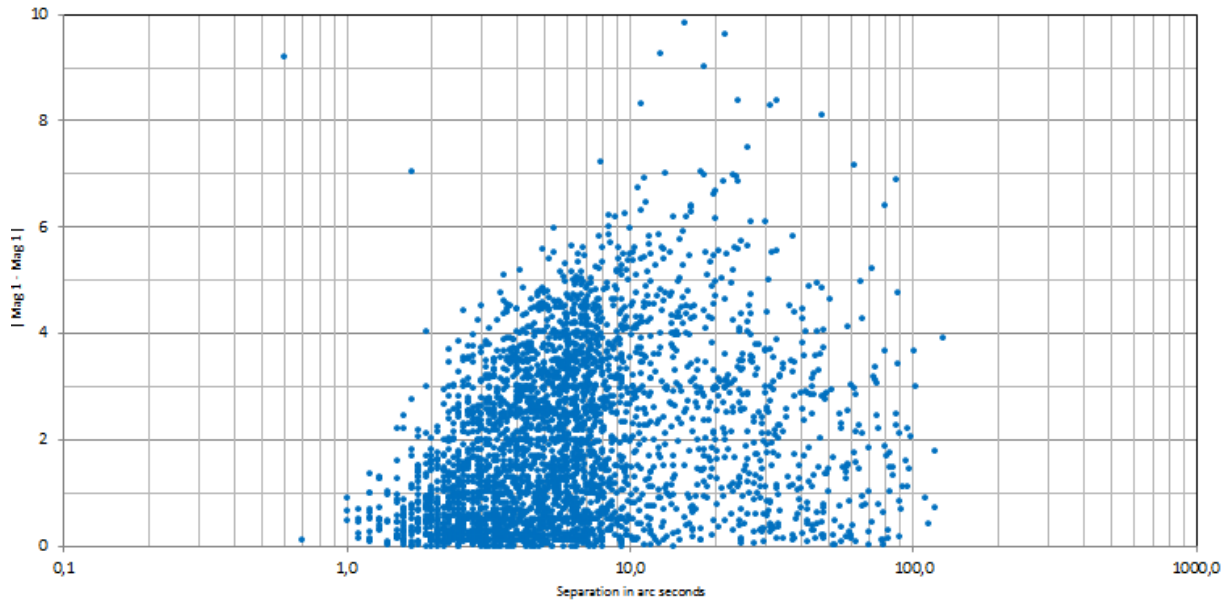


Figure 2: Distribution of the 3193 Espin double stars, $|\text{Mag 1} - \text{Mag 2}|$ over the separation (Schlimmer, 2020).

Espin used for his observations an 17.25-inch reflector but a today's 12-inch Newtonian telescope in combination with a standard CMOS camera is also suitable even in case of suburban observation location.

2. Equipment and Methods

Observations were done with a 12-inch Newtonian telescope in combination with a QHY5L II CMOS Color camera. Focal length is 1500 mm, reproduction scale is about 0.52 arc seconds per pixel. In cases of separation $< 3''$ focal length were sometimes magnified with a Barlow lens. In a few cases the measurement were done with a 5-inch refractor.

For calibration the data sets from different double stars were used. For each data set a regression line was calculated and extrapolated. The calculated separation values for 2021 were used to calibrate own measurements. In case of Castor the separation was calculated with ephemerides by Doc2014g (Dacobo, 2014). Calculation was done with Binary Star Orbit Calculator by Brian Workman (Workman, 1998).

Table 1: Calibration stars.

Double Star	Position	Calculated sep. for 2021	Source
Theta 2 Orionis	WDS05354-0525	52.28	WDS
STFA 7	WDS03311+2744	44.08	WDS
Theta 1 Orionis AD	WDS05353-0523	21.47	WDS
Theta 1 Orionis AC	WDS05353-0523	12.85	WDS
Theta 1 Orionis AB	WDS05353-0523	8.69	WDS
Castor	WDS07346+3153	5.45	Sixth Orbit Catalog

For each measurement a video with 100 or 200 frames were recorded. Every frame is like a single measurement. Data analyses were done with REDUC software Version 5 (Losse, 2016). For each frame separation and position angel will be automatically analyzed by the ELI interface. The standard deviation for measurements of the separation is usually smaller than ± 0.15 arc seconds. The standard deviation for measurements of position angel depends on the separation of both components. For double stars with separation of about 5 arc seconds the standard deviation for position angle is usually ± 1 degree.

3. Data

The following table shows the measurements of separation and position angle of 393 double stars from 2021. Brightness and coordinates are taken from The Washington Double Star Catalog (Mason et al., 2020). Date is given in Julian years. N gives the numbers of observation nights. Usually every double star will be observed only for one night (N=1).

Table 2: Measurements

RA+DEC	Name	MAGS	PA	SEP	DATE	N	NOTES
00001+5400	ES 704	9.5,11.5	115.7	4.28	2021.972	1	
00008+3647	ES 221	8.35,10.31	233.9	15.46	2021.972	1	
00033+3357	ES 2209	9.36,12.5	241.5	4.64	2021.972	1	
00046+4723	ES 1293	10.58,11.43	185.3	5.88	2021.972	1	
00049+4939	ES 864	9.4,10.9	166.5	9.03	2021.972	1	
00060+4937	HU 502	7.66,10.61	104.4	2.63	2021.972	1	
00072+4723	ES 1193	10.83,11.72	64.5	2.26	2021.972	2	
00073+3741	ES 1935	9.7,12.2	137.7	8.96	2021.972	1	
00087+5006	ES 443	9.26,12.2	29.7	4.86	2021.972	1	
00096+4758	ES 1126	9.81,10.92	318.9	6.40	2021.972	1	
00104+4952	ES 2576	8.62,8.72	294.4	76.99	2021.972	1	
00107+4957	HU 503AB	9.22,13.0	27.9	5.25	2021.972	1	
00107+4957	HU 503AC	9.22,11.81	46.1	40.38	2021.972	1	
00112+4933	ES 2577	8.24,8.99	311.1	66.12	2021.972	1	
00133+5150	ES 748	8.05,12.2	358.8	9.96	2021.972	1	
00133+4013	ES 152	8.98,12.5	105.8	7.52	2021.972	1	
00405+5632	H 5 18AD	2.35,8.98	282.8	71.19	2021.030	1	
00426+5736	ES 1806	7.53,12.1	237.0	5.70	2021.030	1	
00495+5440	STII436	10.21,13.0	194.8	8.7	2021.030	1	
00501+5434	ES 937	10.15,10.8	189.8	5.87	2021.030	1	
00527+3316	ES 316	10.9,12.2	299.4	2.71	2021.030	1	
00538+5434	ES 938	10.4,11.0	215.1	4.16	2021.030	1	
01122+5439	ES 756	9.51,11.6	214.9	3.20	2021.030	1	
02011+5331	ES 6	7.99,11.3	205.3	5.80	2021.030	1	
02040+5051	ES 1060	10.9,12.7	257.9	2.90	2021.030	1	
02145+5535	ES 871	9.53,10.2	306.2	4.11	2021.030	1	
02196+5449	ES 950AB	9.58,10.3	102.8	6.91	2021.030	1	
02286+5521	ES 872AB	10.6,11.5	160.8	3.58	2021.030	1	
02598+5420	ES 621AB	9.17,12.09	355.3	7.2	2021.030	1	
03027+0414	BAL2110	9.6,9.9	226.8	9.31	2021.030	1	see sec. 3.1
03311+2744	STFA 7AB	7.41,7.81	234.2	44.14	2021.118	1	5-inch tel.
03311+2744	SMR 60BC	7.81,13.	0.2	12.34	2021.115	1	
03313+2734	STF 401AB	6.58,6.93	269.8	11.45	2021.118	1	5-inch tel.

04069+4251	ES 565	10.70,12.0	26.1	6.51	2021.115	1	
04371+5429	ES 883	11.31,12.08	169.0	4.89	2021.121	1	
04470+5611	ES 1823AB	9.8,11.1	206.3	5.89	2021.115	1	
04477+4511	ES 1319	9.51,12.0	22.0	6.88	2021.121	1	
04498+0658	STT 560AB	3.22,11.31	173.1	72.92	2021.151	1	
04509+3928	ES 240	10.54,12.0	217.6	4.57	2021.115	1	
05064+5424	ES 888AB	7.28,11.8	186.2	6.97	2021.121	1	
05064+5424	ES 888AC	7.28,12.0	245.4	25.95	2021.121	1	
05084+4205	ES 1720AB	10.1,10.5	120.2	3.92	2021.121	1	
05120+4154	ES 1722AB	8.63,11.91	303.6	5.55	2021.121	1	
05133+0252	STF 654AB	4.62,8.50	63.8	6.75	2021.151	1	
05145-0812	STF 668A,BC	0.3,6.8	203.6	9.42	2021.151	1	
05166+4240	ES 573	8.14,11.42	126.3	5.54	2021.121	1	
05205+4019	ES 281	10.18,10.88	215.2	2.39	2021.151	1	
05248+4723	ES 577	10.79,12.6	148.7	3.73	2021.115	1	
05297+6242	ES 171	9.04,10.6	240.9	2.97	2021.178	1	
05338+4044	ES 1725	10.5,10.8	214.2	2.77	2021.115	1	
05351+0956	STF 738AB	3.51,5.45	42.9	4.05	2021.151	1	
05353-0523	STF 748AB	6.55,7.49	32.0	8.73	2021.151	5	5-inch tel.
05353-0523	STF 748AC	6.55,5.06	132.2	12.83	2021.151	5	5-inch tel.
05353-0523	STF 748AD	6.55,6.38	96.6	21.43	2021.151	5	5-inch tel.
05353-0523	STF 748AE	6.55,11.1	353.8	4.44	2021.115	4	
05353-0523	STF 748CF	5.06,11.5	120.8	4.50	2021.115	3	
05354-0555	STF 752AB	2.77,7.73	141.3	11.22	2021.151	1	
05407-0157	STF 774AB	1.88,3.70	166.3	2.40	2021.151	1	Alnitak
05450+3952	ES 172	10.36,11.4	136.8	4.19	2021.121	1	
05451+4151	ES 64	9.4,10.4	74.8	3.54	2021.115	1	
05467+4322	ES 1530	9.9,9.9	198.0	5.26	2021.151	1	
05501+3935	STF 791AB	9.07,9.98	91.3	4.88	2021.121	1	
05524+4649	ES 1321AB	7.84,9.6	351.2	5.50	2021.115	1	
05552+0724	H 6 39AB	0.77,14.5	113.9	36.42	2021.151	1	Beteigeuze
05552+0724	H 6 39AD	0.77,13.5	346.1	71.50	2021.151	1	
05598+4752	ES 1232AB	10.4,12.3	269.9	4.00	2021.151	1	
06031+4100	ES 1729	10.27,12.1	311.2	6.80	2021.244	1	
06088+4242	ES 1628	10.0,11.5	288.5	3.05	2021.244	1	
06090+4907	ES 1073	8.45,12.4	104.2	7.42	2021.244	1	
06139+3943	ES 286	10.3,10.8	63.3	2.46	2021.244	1	
06139+3725	ES 2343	10.2,12.0	141.4	3.29	2021.244	1	
06218+3908	ES 288AB	10.13,10.4	149.0	4.21	2021.244	1	
06231+5157	ES 897	10.03,12.6	92.2	6.54	2021.244	1	
06288-0702	STF 919AB	4.62,5.00	132.8	7.24	2021.151	3	
06288-0702	STF 919AC	4.62,5.39	125.1	9.68	2021.181	2	5-inch tel.
06288-0702	STF 919BC	5.00,5.32	112.4	2.63	2021.151	1	
06311+4253	ES 1630	11.88,12.0	272.7	5.23	2021.151	1	
06324+6044	ES 1891	8.61,11.78	190.9	3.61	2021.115	1	
06329+5314	ES 712	10.4,10.9	252.5	4.86	2021.190	1	
06435+5040	ES 1077	9.6,11.0	96.6	3.32	2021.244	1	
06443+5444	ES 898	9.3,12.4	317.4	8.98	2021.244	1	
06451-1643	AGC 1AB	-1.47,8.44	66.6	11.28	2021.142	1	Sirius
06514+4712	ES 584	11.18,11.61	323.2	3.15	2021.151	1	
06566+4632	STF 979	8.47,9.58	211.7	7.54	2021.178	1	
07003+4710	ES 1238	10.8,11.1	203.5	2.99	2021.178	1	

07005+4628	ES 1239	10.5,11.6	359.9	4.63	2021.178	1
07009+6331	ES 1893	9.48,11.5	158.9	4.77	2021.178	1
07026+5039	ES 1079AB	8.21,11.7	323.1	6.08	2021.244	1
07075+3827	ES 2156	10.7,10.9	220.4	5.91	2021.178	1
07096+3828	STF1021A,BC	9.54,9.6	16.5	4.03	2021.178	1
07121+4931	ES 1080	10.97,12.5	30.5	4.41	2021.246	1
07181+1632	STF1061AB	3.58,10.7	35.9	9.65	2021.227	1
07195+3226	ES 341	10.26,10.72	252.1	3.93	2021.246	1
07261+5021	ES 903	9.44,12.0	246.3	10.86	2021.246	1
07304+3647	ES 2626	8.64,12.2	302.9	13.87	2021.246	1
07443+4522	ES 2627AB	7.64,11.1	280.3	11.26	2021.246	1
07444+2424	STT 179	3.66,10.0	242.5	7.03	2021.227	1
07531+5125	ES 69	10.70,11.9	136.6	5.82	2021.246	1
07548+4309	ES 590	10.3,10.7	73.1	7.76	2021.246	1
07575+4018	ES 1635	10.23,11.5	277.1	7.39	2021.254	1
08004+4243	ES 1387	10.7,11.4	142.2	5.50	2021.254	1
08013+5117	ES 907	10.36,11.6	111.5	6.33	2021.254	1
08027+3211	ES 291	8.64,11.8	345.9	6.88	2021.254	1
08035+2748	ES 2628AB	5.06,12.23	187.1	57.88	2021.254	1
08035+2748	ES 2628AC	5.06,11.47	79.4	83.64	2021.254	1
08058+3435	ES 423	9.3,11.2	299.3	2.76	2021.254	1
08071+3457	ES 424	10.46,11.9	74.5	5.83	2021.254	1
08131+4133	ES 592	9.23,10.98	328.2	2.77	2021.254	1
08210+5328	ES 908	10.5,11.8	329.8	2.55	2021.254	1
08235+2311	STF1218	9.76,11.3	267.6	4.37	2021.227	1
08262+3608	ES 2160	10.8,10.9	343.2	3.48	2021.334	1
08288+5844	ES 1781	10.41,11.0	304.7	4.43	2021.334	1
08402+5147	STF1250AB	10.18,10.40	167.9	21.47	2021.334	1
08404+5145	ES 909AB	7.82,11.54	316.3	58.58	2021.334	1
08467+2846	STF1268	4.13,5.99	308.1	30.60	2021.254	1
09013+1516	STF1300AB	9.47,9.73	179.1	4.76	2021.244	1
09020+4722	ES 598	8.99,10.9	265.9	8.52	2021.334	1
09039+5845	ES 1782	10.00,12.44	332.0	3.70	2021.334	1
09427+4018	ES 301	9.8,11.8	243.4	5.05	2021.334	1
09438+5557	ES 1825	8.02,12.35	43.2	6.19	2021.334	1
09541+4809	ES 602	10.4,11.1	32.0	3.63	2021.334	1
10073+6212	ES 1903	9.51,11.8	266.7	4.62	2021.391	1
10073+5908	ES 1785	9.7,10.8	179.7	3.24	2021.391	1
10082+2648	ES 431AB	8.34,11.5	351.9	35.65	2021.391	1
10082+2648	ES 431AC	8.34,11.17	354.8	40.86	2021.391	1
10082+2648	ES 431BC	11.5,11.17	14.6	5.66	2021.391	1
10241+4034	ES 1394	9.00,10.1	144.7	6.65	2021.391	1
10245+4008	ES 1542	10.7,10.8	201.5	3.64	2021.391	1
10369+4504	ES 1152	10.85,11.33	348.8	2.60	2021.391	1
10381+4527	ES 919	10.75,11.9	322.5	6.90	2021.391	1
10427+4812	ES 603	9.95,12.3	102.5	13.27	2021.391	1
10588+3039	ES 303	10.36,12.4	201.7	7.77	2021.391	1
11007+4244	ES 2637	6.69,10.7	210.3	11.57	2021.391	1
11132+3543	ES 181	10.56,12.2	145.1	5.39	2021.391	1
11383+3845	ES 306	8.89,11.86	341.8	7.00	2021.391	1
11551+4629	STF1579AB,C	6.68,8.32	43.7	3.72	2021.391	1
11551+4629	STF1579AB,D	6.68,6.97	114.2	62.91	2021.391	1

11596+4636	ES 2639	9.36,12.5	53.4	9.59	2021.363	1	
12162+4154	ES 124	8.91,12.7	118.2	7.71	2021.417	1	
12269+2816	SMR 58	4.4,12.	206.5	16.05	2021.417	1	g Com
12307+5352	ES 726AB	10.48,12.4	157.1	9.39	2021.417	1	
12307+5352	ES 726AC	10.48,13.6	177.1	20.4	2021.417	1	
12417-0127	STF1670AB	3.48,3.53	355.7	2.87	2021.411	2	
12429+2555	ES 438	8.89,12.33	285.0	5.73	2021.411	1	
12506+4604	ES 731	8.15,12.7	348.4	11.71	2021.445	1	
13023+4219	ES 606	9.59,12.4	285.6	9.41	2021.445	1	
13114+0938	LDS5771AB	8.80,12.36	169.3	81.77	2021.411	1	Wolf 477
13149-1122	SHJ 162AB	7.11,8.18	44.6	114.20	2021.411	1	Mayer 36
13336+4648	ES 2646	8.93,12.5	342.0	8.87	2021.445	1	
14165+4633	ES 1085	8.71,11.7	176.3	6.04	2021.445	1	
14380+5135	STF1863	7.71,7.80	58.2	0.62	2021.449	1	5x barlow lens
14439+4743	ES 962AB	8.7,11.3	266.0	11.30	2021.477	1	
14514+1906	STF1888AB	4.76,6.95	296.0	5.01	2021.449	1	
14525+1844	BU 31AB	8.53,10.26	225.3	1.83	2021.449	1	2x barlow lens
15018+5128	ES 739	10.51,11.09	161.1	1.92	2021.611	2	2x barlow lens
16051+5426	ES 743	9.71,12.8	11.5	5.60	2021.602	3	
16065+5441	MLB 135	10.11,10.26	96.1	3.42	2021.602	1	
16103+5439	ES 967	8.66,12.3	210.4	8.33	2021.602	2	
16239+6020	ES 1828	10.8,11.4	248.7	3.33	2021.602	1	
16362+5255	STF2078AB	5.38,6.42	104.3	2.93	2021.602	1	
16392+5237	ES 968	10.21,11.4	27.6	5.50	2021.602	1	
16524+6028	ES 1829	10.72,11.5	79.1	8.31	2021.602	1	
17010+4616	ES 1255	8.19,11.7	48.5	7.67	2021.602	1	
17083+5051	ES 77AB	6.45,10.96	279.3	18.61	2021.602	1	
17237+3709	STF2161AB	4.50,5.40	320.9	4.01	2021.687	1	
17245+3657	STT 329	6.35,9.88	12.3	33.0	2021.687	1	
17301+5743	ES 1742	10.83,11.48	28.1	1.62	2021.611	1	2x barlow lens
17341+6011	ES 1795	10.6,11.4	147.2	2.60	2021.609	4	
17372+4309	ES 2660	10.16,10.16	154.7	9.34	2021.726	1	
17383+4500	ES 1257AB	10.45,10.9	296.4	2.71	2021.670	2	2x barlow lens
17383+4500	ES 1257AC	10.45,10.53	123.9	52.26	2021.726	1	
17400+4046	ES 9003	10.8,11.0	52.0	10.16	2021.726	1	
17424+6501	ES 1910	9.93,10.04	54.1	5.06	2021.726	1	
17444+4027	ES 9004	8.10,12.7	246.7	13.2	2021.726	1	
17527+6030	ES 2662	10.32,11.22	108.4	12.2	2021.616	1	
17536+6103	ES 1833	7.95,12.6	261.0	8.09	2021.616	3	
17536+4313	ES 2663	10.60,10.32	333.1	10.07	2021.726	1	
17566+5813	ES 20	10.85,11.08	209.9	17.40	2021.726	1	
18072+6228	ES 1834	10.0,10.3	310.3	3.54	2021.726	1	
18077+5632	SLE 139	10.40,12.6	333.2	6.55	2021.616	1	
18097+5329	BEM 31	9.90,12.3	306.4	11.82	2021.616	1	
18127+5557	ES 643	10.71,12.9	49.4	3.91	2021.616	1	
18138+5341	ES 645	8.94,12.7	83.6	3.10	2021.616	1	
18294+4158	ES 1559AB	9.25,11.45	87.1	77.05	2021.616	1	
18294+4158	ES 1559BC	11.45,12.12	187.7	1.71	2021.616	2	
18353+4314	ES 1422	10.3,11.0	82.3	4.00	2021.687	1	
18369+3846	H 5 39AB	0.09,9.5	184.9	84.46	2021.646	1	
18369+3846	STFB 9AE	0.09,9.5	39.6	84.26	2021.646	1	
18411+4356	ES 1423	10.69,11.32	333.0	4.96	2021.687	1	

18436+4237	ES 478	10.07,10.6	185.0	9.32	2021.687	1	
18439+6039	ES 189AB	10.2,12.2	107.4	3.26	2021.616	3	
18443+3940	STF2382AB	5.15,6.10	344.7	2.15	2021.611	2	
18443+3940	STFA 37AB,CD	4.67,4.56	171.8	209.40	2021.668	1	
18443+3940	STFA 37AD	5.15,5.38	171.8	208.20	2021.668	1	
18443+3940	STFA 37AI	5.15,10.12	137.4	150.36	2021.668	1	
18443+3940	STF2383CD	5.25,5.38	74.6	2.34	2021.641	2	
18443+3940	SHJ 277EF	12.3,12.7	37.1	45.36	2021.668	1	
18451+3756	ES 2020	10.33,12.0	343.4	3.23	2021.733	3	
18452+3914	STF2392AB	9.25,11.07	314.3	2.77	2021.668	1	
18452+3914	STF2392AC	9.25,10.46	172.7	23.75	2021.668	1	
18456+6404	ES 1840	9.69,11.26	215.6	9.09	2021.687	1	
18467+4303	ES 1425	9.89,10.30	231.6	4.38	2021.635	1	
18481+4122	ES 1561	9.6,11.5	125.9	6.41	2021.687	1	
18494+6528	ES 1912	10.33,11.9	21.0	7.60	2021.635	1	
18521+4323	ES 1427	10.76,14.0	117.9	4.39	2021.635	1	
18541+3103	ES 2421	10.54,11.2	69.0	7.66	2021.635	1	
18550+6143	ES 2669	10.2,10.6	165.6	11.91	2021.687	1	
18555+4411	ES 1428AB	8.68,12.71	103.0	27.20	2021.635	1	
18555+4411	ES 1428BC	13.5,13.7	117.8	2.38	2021.635	2	
18559+3707	ES 2486	10.5,11.6	269.2	7.87	2021.363	1	
18569+3112	ES 2422	8.96,12.0	177.9	5.68	2021.665	1	
18593+6347	ES 1844AB	9.6,10.5	18.5	2.76	2021.665	1	
19002+5207	ES 651	10.99,11.3	137.8	5.05	2021.635	1	
19021+5216	STF2450A,BC	6.50,9.51	299.6	5.16	2021.642	2	
19047+3334	ES 2237	10.28,10.62	218.2	9.87	2021.363	1	
19052+5201	ES 978	9.9,10.0	198.9	5.06	2021.646	1	
19052+4955	ES 2673AB	6.43,11.7	130.2	11.99	2021.687	1	
19052+4955	WAL 103AC	6.43,11.68	29.0	82.43	2021.687	1	see sec.3.2
19063+3158	ES 2367	10.4,11.2	140.4	6.78	2021.646	1	
19068+5006	ES 1094	10.18,12.8	149.4	6.19	2021.646	1	
19077+5057	ES 979AB	9.73,12.0	193.5	8.31	2021.687	1	
19077+5057	ES 979AC	9.73,11.56	46.5	19.20	2021.687	1	
19077+3402	ES 2288	11.17,11.56	59.5	4.51	2021.635	1	
19084+3831	ALI 880	11.9,12.9	61.8	6.69	2021.646	1	
19086+3831	ALI 881	7.76,12.7	268.1	14.7	2021.646	1	
19086+3755	STF2472AB	8.38,10.44	339.7	22.74	2021.646	1	
19086+3755	STF2472AC	8.38,10.29	347.8	75.44	2021.646	1	
19086+3755	STF2472AD	8.38,10.45	344.2	79.20	2021.646	1	
19086+3755	STF2472AE	8.38,12.9	332.1	53.27	2021.646	1	
19086+3755	STF2473CD	10.29,10.45	293.9	6.22	2021.646	1	
19089+5954	MLB 77	10.67,11.10	180.2	6.52	2021.646	1	
19098+3849	ES 2035	10.0,11.1	173.2	3.06	2021.646	2	
19100+5124	ES 790	9.32,12.1	115.8	4.87	2021.665	1	
19126+6740	BUP 186AB	3.17,12.58	340.5	80.38	2021.687	1	
19126+6740	BUP 186AC	3.07,12.00	20.6	131.21	2021.687	1	
19132+3125	ES 2423	10.5,10.5	9.1	3.22	2021.665	1	
19139+5523	ES 981	9.65,11.8	81.6	2.62	2021.668	2	
19147+5946	ES 192	9.82,12.2	100.2	4.67	2021.646	1	
19151+5946	ES 193	9.12,11.9	134.5	8.42	2021.646	1	
19159+5048	ES 2676	9.42,14.6	188.2	8.29	2021.665	1	
19162+3621	ES 2176	10.14,12.7	201.4	6.06	2021.665	1	

19164+3808	SHJ 292AB	4.48,10.14	70.0	99.19	2021.665	2	
19164+3808	SHJ 292AC	4.48,11.1	128.4	101.71	2021.665	2	
19165+5052	ES 652	10.65,12.6	73.4	6.44	2021.665	1	
19192+3715	ES 2113	11.1,11.1	335.6	4.74	2021.665	1	
19193+4217	ES 1562AB	9.39,9.8	325.2	6.09	2021.674	1	
19199+5130	ES 791	9.27,12.1	307.6	11.06	2021.668	1	
19212+3720	ES 2491	10.7,10.8	359.2	4.67	2021.668	1	
19217+2534	ES 483	7.30,12.0	3.4	13.67	2021.667	1	
19219+6306	MLR 50	8.59,11.94	346.9	3.09	2021.679	1	
19227+5336	ES 984BC	12.8,13.3	312.5	5.13	2021.674	1	
19228+4120	ES 1661	10.39,12.9	152.5	3.41	2021.674	1	
19238+4021	ES 1662	10.4,12.2	70.6	3.24	2021.674	1	
19248+2856	ES 484AB	9.42,12.7	317.9	9.27	2021.679	1	
19248+2856	ES 484AC	9.42,9.71	333.5	23.09	2021.679	1	
19258+2846	STF2522	7.74,8.79	345.2	4.46	2021.679	1	
19267+5125	ES 792	9.56,11.5	249.2	8.27	2021.674	1	
19275+5005	ES 1096	10.15,12.6	159.1	6.87	2021.674	1	
19282+5447	ES 654	7.55,12.8	190.9	7.34	2021.674	1	
19296+3453	ES 2240AB	9.48,12.3	349	11.89	2021.679	1	
19296+3453	ES 2240BC	12.3,12.8	156.3	2.76	2021.679	1	
19299+6300	ES 1847	10.83,12.0	226.0	3.43	2021.679	1	
19301+2503	POU3863	7.96,12.1	295.2	6.67	2021.679	1	
19317+5300	STF2542AB	8.86,9.61	249.0	11.51	2021.679	1	
19333+5249	ES 129AB	9.96,10.86	221.9	3.26	2021.698	2	
19339+2723	ES 487	10.07,12.5	332.4	4.96	2021.679	1	
19340+2729	ES 488	10.26,10.60	54.6	2.95	2021.679	1	
19343+6250	ES 1848	9.38,11.1	318.1	6.69	2021.715	1	
19358+4321	ES 1434	10.3,11.4	219.4	2.93	2021.715	1	
19364+4808	ES 491AB	10.15,10.6	54.4	9.95	2021.715	2	
19364+4808	ES 491AC	10.15,11.80	249.1	22.92	2021.715	1	see sec. 3.3
19365+6503	ES 197	8.98,11.0	24.2	9.11	2021.715	1	
19366+4327	ES 490AB	10.15,10.22	223.0	64.05	2021.715	1	
19366+4327	ES 490BC	10.22,11.4	179.8	3.6	2021.715	1	
19377+6203	STI 907	11.64,12.5	16.0	4.57	2021.775	1	
19378+4328	ES 493	11.36,10.89	316.6	4.24	2021.715	1	
19388+6456	ES 198	9.57,10.43	312.6	2.90	2021.715	1	
19389+4808	ES 1165	11.0,11.1	298.7	4.37	2021.715	1	
19392+5337	A 1401	9.88,10.90	176.9	3.63	2021.715	1	
19393+3106	ES 2425	10.0,11.0	24.1	4.35	2021.715	1	
19421+5319	ES 657AB	10.32,11.9	118.7	2.98	2021.715	1	
19461+4458	ES 83	10.3,10.3	210.4	7.16	2021.775	1	
19467+3124	ES 2426	10.2,11.8	263.1	4.11	2021.775	1	
19475+6125	ES 1849	9.48,12.7	157.4	3.86	2021.775	1	
19476+6403	ES 1917	8.40,12.5	339.5	8.03	2021.775	1	
19482+7016	STF2603	4.01,6.87	22.1	2.96	2021.687	1	
19484+3144	ES 354	8.96,11.9	333.9	9.73	2021.810	1	
19487+4242	ES 1564	10.6,12.0	355.7	7.23	2021.810	1	
19492+4238	ES 1565AB	9.79,12.60	32.0	32.73	2021.810	1	
19492+4238	ES 1565BC	12.60,13.7	49.6	4.67	2021.810	1	
19495+3843	ES 84AB	6.22,11.1	158.0	10.33	2021.810	1	
19495+3843	ES 84AC	6.22,13.2	94.0	22.1	2021.810	1	
19496+5454	ES 659	10.99,11.21	171.47	14.87	2021.810	1	

19500+4509	ES 23AB	8.27,12.60	136.3	8.62	2021.810	2	
19500+4509	ES 23AD	8.27,10.01	326.8	30.72	2021.810	2	
19501+5439	STF2598	8.17,10.58	149.6	11.86	2021.810	1	
19514+3746	ES 2114	9.38,12.7	42.8	13.57	2021.810	1	
19517+3108	ES 357AB	7.12,12.4	309.4	10.06	2021.810	1	
19517+3108	STT 389AC	7.12,9.53	183.7	12.71	2021.810	1	
19522+3139	ES 356	10.03,10.9	344.6	6.01	2021.810	1	
19524+4648	ES 1267	9.16,12.5	161.2	4.98	2021.775	2	
19527+3157	A 377	9.09,13.5	262.7	3.91	2021.810	1	
19537+4936	ES 2685	8.54,11.8	250.4	32.88	2021.810	1	see sec. 3.4
19540+4915	ES 2686	7.95,11.0	303.9	19.06	2021.810	1	
19546+4940	TDS1023	11.19,11.30	347.3	2.09	2021.810	1	
19553+3435	ES 200	10.81,11.36	230.5	4.46	2021.775	1	
19586+4341	ES 1436	10.1,11.5	184.5	2.18	2021.810	1	
20020+3522	ES 243	10.81,12.0	279.5	5.08	2021.813	1	
20024+3519	ES 202AB	9.2,10.9	99.8	17.84	2021.813	1	
20024+3519	ES 202AC	9.2,11.8	163.8	11.83	2021.813	1	
20024+3519	ES 202AD	9.2,11.8	133.5	23.05	2021.813	1	
20024+3519	ES 202AM	9.2,13.1	223.2	11.62	2021.813	1	
20024+3519	ES 202AN	9.2,14.4	101.7	22.76	2021.813	1	
20024+3519	ES 202AO	9.2,14.4	179.9	3.72	2021.813	1	
20028+3158	ES 359AB	6.51,12.6	134.9	30.47	2021.813	1	
20028+3158	ES 359BC	12.6,14.0	67.5	6.07	2021.813	1	
20028+3142	ES 358	9.46,12.00	200.2	8.03	2021.813	1	
20039+4411	ES 85AB	10.52,11.20	37.0	2.16	2021.813	1	
20039+4411	ES 85AC	10.52,12.5	86.2	10.58	2021.813	1	
20039+4411	ES 85AD	10.52,13.1	307.6	11.06	2021.813	2	
20061+4500	ES 1329	8.13,10.6	209.9	9.27	2021.813	1	
20102+3644	ES 87	9.34,10.39	297.7	8.53	2021.895	1	
20103+3643	New	13.7,13.9	91.8	2.94	2021.895	1	see sec. 3.5
20104+3644	SEI 945AB	9.5,11.0	274.0	5.89	2021.895	1	
20104+3644	SEI 946AC	9.5,11.0	291.8	15.03	2021.895	1	see sec. 3.6
20105+3614	SEI 947	12.6,12.6	291.8	15.03	2021.895	1	see also sec. 3.6
20123+4505	ES 1268	9.47,11.7	149.6	8.16	2021.895	1	
20131+4911	ES 502	8.01,10.89	219.9	13.98	2021.895	1	
20136+4644	SMR 68FJ	13.9,15.1	218.3	3.99	2021.715	1	
20136+4644	SMR 68HK	11.74,10.87	262.5	8.99	2021.715	1	
20143+4648	ES 27	10.58,10.61	337.0	4.08	2021.895	1	
20146+5349	ES 987	9.96,10.6	292.6	7.88	2021.895	1	
20146+3855	ES 2047AB	9.48,11.23	174.3	33.19	2021.895	1	
20146+3855	ES 2047BC	10.6,10.8	196.7	4.67	2021.895	1	
20150+3500	ES 205	9.22,11.6	197.6	7.12	2021.895	1	
20155+3713	ES 2189	9.64,12.8	136.3	3.26	2021.895	1	
20168+4158	ES 1568AB	10.86,12.23	291.5	12.80	2021.895	1	
20168+4158	ES 1568BC	12.23,12.3	7.4	2.29	2021.895	1	
20173+5201	ES 660AB	10.19,10.26	303.3	29.93	2021.895	1	
20173+5201	ES 660BC	10.26,10.33	288.7	9.33	2021.895	1	
20456+3043	STF2726	4.33,9.53	73.8	5.75	2021.775	1	
21069+3845	STF2758AB	5.20,6.05	153.8	31.89	2021.775	1	
21069+3845	STF2758AH	5.35,9.97	263.0	134.0	2021.775	1	
21069+3845	SMR 1AI	5.35,10.74	235.7	49.29	2021.775	1	
21069+3845	SMR 40AO	5.35,12.65	275.4	176.61	2021.775	1	

21069+3845	SMR 40AP	5.35,12.84	283.5	166.48	2021.775	1	
21069+3845	SMR 40AQ	5.35,13.19	295.3	76.07	2021.775	1	
22030+5131	ES 1109	10.4,12.4	113.1	5.03	2021.895	1	
22033+4646	ES 529	9.09,11.3	72.0	5.51	2021.893	1	
22035+4841	ES 530AB	8.08,11.24	190.0	8.54	2021.893	1	
22064+4716	ES 532	10.34,10.76	241.8	9.94	2021.893	1	
22069+3335	ES 385AB	8.93,10.4	73.2	7.70	2021.893	1	
22133+3207	ES 388	10.05,10.6	264.1	7.68	2021.893	1	
22149+4553	ES 533	9.69,12.7	n.a.	n.a.	2021.893	1	see sec. 3.7
22155+3454	ES 215	8.81,12.5	141.0	7.97	2021.895	1	
22155+3450	ES 214	9.9,12.3	171.9	3.85	2021.895	1	
22175+3338	ES 2267	10.9,12.4	237.8	2.48	2021.895	1	
22212+4227	ES 1589AB	9.94,11.0	178.7	9.03	2021.895	1	
22270+4709	ES 1285	10.61,11.9	136.2	3.91	2021.895	1	
22289+4654	ES 538	9.72,10.70	66.3	3.37	2021.893	1	
22319+5527	ES 1024	9.32,11.4	257.4	4.63	2021.895	1	
22328+4212	ES 1592	10.05,12.1	312.5	7.53	2021.895	1	
22343+4849	ES 839AB	10.1,10.9	101.5	29.79	2021.893	1	
22343+4849	ES 839BC	10.9,11.7	76.2	5.28	2021.893	1	
22356+4307	ES 1469	9.55,11.9	34.9	5.46	2021.895	1	
22389+4754	ES 842	9.6,10.4	114.5	3.04	2021.893	1	
22407+4851	ES 844AB	10.4,12.4	39.77	4.50	2021.893	3	
22435+3114	ES 393BC	9.01,12.2	263.6	9.93	2021.895	1	
22504+4821	ES 849	8.60,12.9	9.3	9.72	2021.893	1	
22518+4804	ES 851	10.14,10.8	264.4	8.76	2021.893	1	
22522+4734	ES 852	9.10,10.7	326.9	7.22	2021.893	1	
22550+4842	ES 855	10.7,11.3	231.0	2.41	2021.893	1	
23033+4904	ES 856	9.79,12.5	6.3	7.71	2021.895	1	
23107+4137	ES 1703	10.8,12.3	117.6	3.91	2021.969	1	
23126+4645	ES 1290AB	10.5,11.6	68.72	3.03	2021.969	1	
23126+4645	ES 1290AC	10.5,12.5	283.3	14.06	2021.969	1	
23210+3709	ES 2001	10.89,12.2	296.7	8.79	2021.969	1	
23215+4756	ES 698	8.84,11.6	n.a.	n.a.	2021.969	1	see sec. 3.8
23253+3528	ES 2136	10.3,12.0	358.1	3.62	2021.969	1	
23257+4800	ES 857	10.5,11.8	167.5	3.25	2021.969	1	
23271+5302	ES 1044	10.4,12.4	264.8	2.68	2021.969	1	
23375+4832	ES 859AB	8.49,11.9	218.0	89.72	2021.969	1	
23375+4832	ES 859BC	11.9,11.9	83.7	3.07	2021.969	1	See sec. 3.9
23380+5249	ES 2729	8.08,9.53	142.9	19.82	2021.969	1	
23407+4803	ES 699	10.0,11.3	215.8	8.00	2021.969	1	
23460+6013	ES 1767	10.85,12.9	38.4	5.47	2021.969	1	
23461+6028	STF3037AB	7.35,9.20	209.8	2.31	2021.969	1	
23461+6028	STF3037AC	7.35,9.96	189.4	29.39	2021.969	2	
23461+6028	STF3037AD	7.35,10.86	233.4	52.66	2021.969	1	
23461+6028	STF3037AE	7.35,9.70	62.6	110.26	2021.969	1	
23486+6116	ES 1931	8.98,12.2	245.1	8.70	2021.969	1	
23584+5123	ES 37AB	8.68,13.2	267.5	21.90	2021.969	1	
23584+5123	ES 37AC	8.68,11.00	317.4	31.3	2021.969	1	
23591+5658	ES 38	9.78,10.71	237.0	24.88	2021.969	1	

3.1. WDS03027+0414, BAL2110

For BAL2110 the difference in brightness was found about 0.6 magnitudes instead of 0.3 magnitudes. Values for separation and position angle matches with WDS entries. In cases of not overexposed frames REDUC software delivers good values for differences in brightness which can be used for control the target.

3.2 WDS19052+4955, ES 2673AB, WAL 103AC

Measurements for ES 2673AB matches with WDS entries but not for WAL 103AC. There is a large deviation for angle and distance between the WDS data and the authors measurements, but no error could be found in the evaluation.

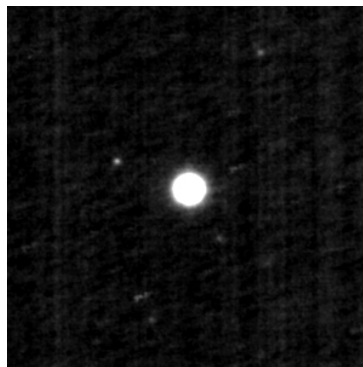
3.3 WDS19364+4808, ES 491AC

Measurements for ES 491AB matches very well with WDS data but for ES 491AC a large deviation for angle between the WDS data and authors measurements could be found. In evaluation no error could be found.

3.4 WDS19537+4936, ES 2685

A companion in a distance of 6-8 arc seconds couldn't be found. Next companion has a distance of about 32.88 arc seconds and a position angle of 250.4 degree. Exposure time was 1s.

Figure 3 : Image of ES 2685, 100 frames stacked, exposure time 1 s



3.5 New Double star at 20°10'28.142 + 36°43'28.07

In a distance of 38 arc seconds from SEI 945A (see sec. 3.6) a new double star could be found. Its distance is about 3 arc seconds, position angle is about 92 degrees. Brightness is only 13.7 mag. Exact position is 20°10'28.142 + 36°43'28.07 (SIMBAD).

Figure 4 : Image of the of ES 87 and SEI 945 with new double star.



3.6 WDS20104+3644, SEI 945AB, SEI 946AC and WDS20105+3614, SEI 947

Measurements of SEI 945AB are in good agreement with the values in the WDS, but there is a large difference to SEI 946AC. Measured difference in brightness matches with the WDS data very well but separation and position angle doesn't fit. There is also a note in the WDS catalog about SEI 946AC with position angle of 292 degree and separation of 15.1 arc seconds which matches with the authors measurements. Also SEI 947 matches with the authors measurements for AC, except the difference in brightness. In this interpretation the listed coordinates in WDS catalog for SEI 947 looks like a typing error and should be checked again. Finally it looks like a mix-up between SEI 945AB, SEI 946AC and SEI 947 which can easy be solved with SEI 945AB and SEI 945AC, see fig. 4 above.

3.7 WDS22149+4553, ES 533

Secondary component could not be found. Estimated distance is about 4-5 arc seconds, difference in brightness is 3 magnitudes. If $|\text{Mag 1} - \text{Mag 2}| \leq \text{separation}$, the double star can be separated with the used 12-inch Newtonian telescope (Schlimmer, 2018). In WDS catalog only 3 measurements are currently included. Last measurement is from 2010 with a separation of 4.5 arc seconds, so it isn't clear why it couldn't be separated.

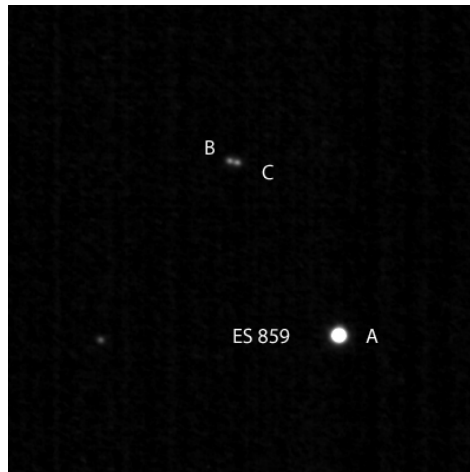
3.8 WDS23215+4756, ES 698

Secondary component could not be found. In WDS catalog only 2 measurements are included with first separation from 1908 of 3.2 arc seconds and last measurement from 2015 with a separation of 2.4 arc seconds. Difference in brightness is about 2.8 magnitudes. In this case according to my experience the distance between both components is ≤ 2.8 arc seconds.

3.9 WDS23375+4832, ES 859BC

ES 859AB and ES 859BC naming of components is inconsistent. In WDS the values for ES 859AB and ES 859CB are given. Fig. 5 shows a stacked picture from best 36 video frames.

Figure 5 : Image of ES 859, 36 frames were stacked



4. Discussion

With the exception of three double stars, all others could be separated, and distance and position angle were measured. For ES 2685, ES 533 and ES 698, the respective companion could not be found. In case of ES 2685 and ES 533 it's a little surprise, since the companions should be far enough away that the main component does not outshine it. Since there are only a few measurements, these systems should also be recorded as targets by other double star observers.

In the case of ES 859, the entries in the WDS for BC in relation to AB were swapped. There is also a mixture of the components SEI 945AB, SEI 946AC and SEI 947. SEI 947 is identical with SEI 945AC. SEI 945, SEI 946 and SEI 947 can be described by SEI 945ABC.

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References:

Docobo, J.A. (2014), Ephemerides taken from Sixth Catalog of Orbits of Visual Binary Stars, Rachel A. Matson, Stephen J. Williams, William I. Hartkopf & Brian D. Mason, U.S. Naval Observatory, Washington, DC, <http://www.astro.gsu.edu/wds/orb6.html>

Losse, Florent (2016), Reduc Software, <http://www.astrosurf.com/hfosaf/uk/tdownload.htm#reduc#>

Mason, B.D., Wycoff, G.L. and Hartkopf, W.I. (2020), The Washington Double Star Catalog, Astrometry Department, U.S. Naval Observatory, <http://www.astro.gsu.edu/wds/>

Rachel A. Matson et al. (2021), Sixth Catalog of Orbits of Visual Binary Stars, U.S. Naval Observatory, Washington, DC, <http://www.astro.gsu.edu/wds/orb6.html>

Schlimmer, S. Joerg (2018), Double Star Measurements with a 12-inch Newtonian Telescope, Annual Report of 2017, Journal of Double Star Observations, Vol. 14 No. 4, 741-749

Schlimmer, S. Joerg (2019), Double Star Measurements Using a CMOS Camera, Annual Report of 2018, Journal of Double Star Observations, Vol. 15 No. 4, 536-543

Schlimmer, S. Joerg (2020), Homepage, http://epsilon-lyrae.de/Doppelsterne/Artikel/Doppelsterne_Geschichte_Fortsetzung.html

Schlimmer, S. Joerg (2021), Double Star Measurements with a 12-inch Newtonian Telescope, Annual Report of 2019, Journal of Double Star Observations Vol. 17, No. 1

Workman, Brian (1998), Binary Star Orbit Calculator, spreadsheet, link for download doesn't exist anymore