

Calibration Binaries

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ABSTRACT

Two Excel Spreadsheet files are offered to help calibrate telescope or camera image scale and orientation with binary stars for any time. One is a personally selected list of fixed position binaries and binaries with well-determined orbits, and the other contains all binaries with published orbits. Both are derived from the web site of the Washington Double Star Library. The spreadsheets give the position angle and separation of the binaries for any entered time by taking advantage of Excel's built in iteration function to solve Kepler's transcendental equation.

1. Background

When I first arrived at the Starfire Optical Range (SOR) in 1991 as the first true astronomer, it became apparent that there was a need for a list of binary stars for calibrating the emerging high angular resolution astronomy technique of adaptive optics (AO) being developed at the SOR under Bob Fugate. I turned to the resources of the Washington Double Star (WDS) Catalog (<http://ad.usno.navy.mil/wds/>) maintained by the United States Naval Observatory which keeps various lists of binary stars. Initially, I formed a list for the 1.5 m telescope, the main telescope at the time, which because of its small aperture required rather bright stars. That catalogue of Bright Binaries was developed by hand-picking through the lists of the WDS to find wide and close bright binaries with equal and unequal magnitude differences between components. At the separations we were dealing with, binaries with known orbits were the best choices for calibrating our system since their orbits could be used to predict their orientation and separation, and otherwise the components might move with respect to each other over the course of years or even months. My lists carried predicted appearances over a ten year period, but only for one date per year.

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Eventually, I turned the local Bright Binary Catalogue into an Excel Spreadsheet when I discovered a feature that solved transcendental equations by self- or circular-referencing cells. This allowed me to produce a spreadsheet that would calculate the appearance for any binary system with an orbit for any date entered. At the heart of using published orbits to predict positions and distances of components is the solution of Kepler's transcendental equation:

$$E - e \sin E = m \quad ,$$

where m is the mean anomaly (angle), e is the eccentricity, and E is the desired eccentric anomaly. It is clear that E has to be found by iterating, a capability in Excel Spreadsheets. Entering the orbital elements (usually in hidden rows or columns in my spreadsheets), and then using the iterative feature of self-referencing cells, allows the complete calculation of predicted binary star positions.

Since others may find these useful, I offer two spreadsheets, Calibration Binaries and All Binaries with Orbits. The first, containing 398 pairs, evolved from my original files, and the second, with 2192 entries, is simply all binaries with published orbits as listed in the Sixth Catalog of Orbits of Visual Binaries at the WDS. A Foreword is the first page of each, and should be read before using, although simply entering the time, date, and longitude and latitude is all that is needed to calculate predicted positions. Both sets of Spreadsheets are discussed below, and are available from me at afrl.rds.workflow@kirtland.af.mil. While the aim is to provide precise position angles and separations with these spreadsheets, the magnitudes and magnitude differences of the stars are only provided as a guide. No claim is made for photometric accuracy, since it can be quite difficult to measure relative binary star magnitudes for close pairs.

2. Calibration Binaries

Originally called Bright Binaries, this spreadsheet is composed of six sheets. The first four list my personally culled list of binaries, either those with good orbits or those that are fixed – showing little apparent motion between components. For the latter I simply extrapolate any motion from the first measurements (often back to the time of the Revolutionary War), through the latest, to the time entered in the spreadsheet. These four sheets contain all binaries north of Declination -20 , with separations between $0.15''$ and $10''$, having a combined V magnitude brighter than 5.0, and no more than a four magnitude difference between components. The magnitude constraints limit the faintest equal component theoretical binary pair to two 5.75 magnitude stars, and the faintest possible star being a 9.0 magnitude component attached to a 5.0 magnitude primary. The

fifth sheet (Others) contains the calibration list from the WDS, less the stars that appear on the first four sheets. Thus, Sheet 5 is a hodge-podge of binaries with reasonably well known orbits. And finally, additional binaries can be entered on Sheet 6.

3. All Binaries with Orbits

Using the Sixth Catalog of Orbits of Visual Binaries from the WDS, the second spreadsheet is one long compilation of all binaries with published orbits, no matter how accurate. There are no restrictions on Declination or magnitudes. While many are not necessarily suitable for calibration, measuring a dozen or more of these should fulfill the purpose of calibration.

4. Afterword

A word of warning is due here. Some of the objects in these lists may prove to be poor calibrators because they may soon be 'off-orbit'. In other cases I may have exhibited poor judgement, or even been erroneous, in including some of them. It is always prudent to make many observations of several stars, and fearlessly eliminate outliers.

While I take no real credit for any advancement in double star work, other than pointing out Excel's Spreadsheet iteration capability, the keepers of the Washing Double Star Library should be recognized for their important work: Brian D. Mason, Gary L. Wycoff, and William I. Hartkopf. Much more data and information is available at the WDS, and the keepers there are more than willing to provide assistance for interested users.

Wide Binaries: 2.0'' < Sep < 10''												Date				UT	
Unequal Components: 2 < Δ mag < 4												2011.45			4.00	7.00	1
HR	Name	RA	2000	Dec	V ₁	V ₂	Spect ₁	Spect ₂	P (yrs)	PA	Sep (")	Grade	Alt	Alt			
603	γ ² And A(BC)	2 3	54.0	42 19 47	2.31	5.02	K3	B8		63	9.5		-13	0			
604	γ ² And BC	2 3	54.7	42 19 51	5.1	6.3	B8	A0	63.67	97.5	0.19	2	-13	0			
707	ι Cas AC	2 29	4.0	67 24 9	4.65	8.7	A3	K3		114	7.3		12	18			
	AB	2 29	4.0	67 24 9	4.65	6.87	A3	F5		231	2.7		12	18			
	Aa	2 29	4.0	67 24 9	4.65	8.48	A3	G6	47.05	36.3	0.61	5	12	18			
804	γ Cet	2 43	18.0	3 14 9	3.54	6.18	A1			298	2.3		-52	-36			
1318	39 Eri	4 14	23.8	-10 15 23	5.03	8.53	K2			146	6.7		-55	-60			
1705	κ Lep	5 13	13.9	-12 56 29	4.43	6.77	B9			357	2.2		-46	-68			
1698	ρ Ori	5 13	17.3	2 51 40	4.62	8.50	K2			63	6.9		-36	-52			
2456	15 Mon	6 40	58.7	9 53 44	4.66	7.79	O7			214	2.9		-15	-42			
2564	38 Gem	6 54	38.6	13 10 40	4.75	7.80	F0	G4	1943.80	324.6	6.98	5	-10	-38			
3482	ε Hya (AB)C	8 46	46.6	6 25 8	3.49	6.66	F8		990.00	305.9	2.89	4	8	-27			
	AB	8 46	46.6	6 25 8	3.80	5.3	F8		15.05	168.1	0.27	1	8	-27			
3616	σ ² UMa	9 10	23.3	67 8 3	4.87	8.85	F7		1141.30	349.4	4.19	5	36	20			
3690	38 Lyn	9 18	50.7	36 48 9	3.92	6.09	A3			225	2.6		29	0			
4399	ι Leo	11 23	55.5	10 31 45	4.06	6.71	F4		186.00	99.0	2.01	2	42	5			
5506	ε Boo	14 44	59.2	27 4 27	2.58	4.81	K0	A0		343	2.8		81	55			
5544	ξ Boo	14 51	23.3	19 6 4	4.76	6.95	G8	K5	151.60	306.9	5.92	2	73	52			
5978	ξ ¹² Sco AC	16 4	21.6	-11 22 25	5.16	7.3	F7	G1	1514.43	44.4	7.55	5	38	40			
	ξ ¹ Sco AB	16 4	21.6	-11 22 25	5.16	4.87	F7		45.90	357.7	0.98	1	38	40			
6923	39 Dra	18 23	54.5	58 48 2	5.06	8.07	A1		3962.50	348.6	3.75	5	45	64			

Screen Capture of 'Wide, Unequal Binaries' sheet. Notice the other sheets along the bottom.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	WDS	HIPPARCOS	RA	2000.0	Dec	V1	V2	V2-V1	PA	Sep (")	Grade	Alt 4 UT	Alt 7 UT	Alt 10 UT							
2	00000-1930	2	00 00	00.91	-19 29	55.8	9	.	216.6	0.009	9	-54	-18	16							
3	00003-4417	25	00 00	19.10	-44 17	26.0	6.8	7.56	53.5	0.080	5	-61	-29	-3							
4	00014+3937	110	00 01	23.69	39 36	38.9	9.09	9.77	169.7	1.249	4	-8	16	48							
5	00022+2705	171	00 02	10.15	27 04	56.1	5.8	8.9	286.0	0.769	2	-19	9	44							
6	00024+1047	190	00 02	25.33	10 46	35.9	9.37	9.91	73.1	0.169	4	-33	-1	36							
7	00026-0829	210	00 02	38.92	-08 29	16.6	9.82	10.07	344.2	0.237	5	-48	-12	23							
8	00046+4206	365	00 04	36.60	42 05	33.2	6	.	318.4	0.098	4	-6	17	48							
9	00048+3810	385	00 04	46.84	38 10	25.8	10.02	10.18	26.5	0.808	4	-10	14	47							
10	00053-0542	443	00 05	20.15	-05 42	28.2	4.63	.	247.1	0.006	9	-46	-11	25							
11	00055+3406	461	00 05	29.06	34 06	20.4	8.2	9.76	307.1	0.188	3	-13	12	46							
12	00057+4549	473	00 05	40.28	45 48	44.8	8.98	10.19	254.3	326.847	5	-3	18	48							
13	00057+4549	473	00 05	40.28	45 48	44.8	8.98	9.15	187.0	5.934	4	-3	18	48							
14	00057+4549	473	00 05	40.28	45 48	44.8	8.98	9.15	186.6	6.034	4	-3	18	48							
15	00063+5826	518	00 06	15.54	58 26	12.1	6.42	7.32	349.5	1.549	2	8	25	47							
16	00084+2905	677	00 08	23.17	29 05	27.0	2.22	4.21	255.4	0.018	2	-18	9	43							
17	00085+3456	689	00 08	28.39	34 56	04.3	8.27	8.31	74.0	0.132	2	-13	12	45							
18	00090-5400	730	00 09	02.35	-54 00	07.1	6.74	8.07	33.0	0.354	4	-59	-33	-11							
19	00090-5400	730	00 09	02.35	-54 00	07.1	6.74	8.07	19.7	0.414	4	-59	-33	-11							
20	00093+2517	754	00 09	15.63	25 16	56.3	7.77	.	177.2	0.008	9	-22	6	42							
21	00093+7943	760	00 09	19.83	79 42	52.7	6.68	6.89	16.1	0.876	3	26	32	40							
22	00094-2759	761	00 09	21.02	-27 59	16.5	6.13	6.24	258.9	1.342	5	-60	-24	8							
23	00095+1907	768	00 09	27.98	19 06	56.5	8.29	9.98	255.3	0.384	5	-27	3	39							
24	00098-3347	794	00 09	50.12	-33 47	19.3	9.56	9.74	117.9	0.821	5	-62	-26	4							
25	00106-7313	865	00 10	38.31	-73 13	28.0	6.97	8.55	200.4	0.449	5	-48	-36	-25							
26	00121+5337	981	00 12	08.05	53 37	26.1	7.25	8.46	315.2	0.343	2	3	21	47							
27	00122+4647	984	00 12	10.31	46 46	29.7	9.7	10.35	119.2	0.227	5	-3	18	47							
28	00125+1434	999	00 12	30.12	14 33	49.3	8.59	.	89.2	0.006	9	-31	-1	36							
29	00126-1143	1005	00 12	22.15	-11 41	24.7	8.08	8.08	262.8	0.224	5	-53	16	10							

Screen Capture of 'Sixth Catalog of Orbits of Visual Binaries' sheet. Unlike the Calibration Binaries spreadsheet, date, time, longitude, and latitude are entered on the last sheet, which also contains all of the orbital elements in hidden cells.