New Double Stars Within 25 Parsecs

George Gatewood and Carolyn Gatewood
Sirius Two Observatory
665 Forest Pine Drive
Ball Ground GA, 30107
Gatewood@pitt.edu

Abstract: We list coordinates, positions angles, separations magnitudes, proper motions, parallaxes, and radial velocities for new doubles stars we found in the Gaia Data Release II.

Introduction

We have been following the Gaia mission for some time. The precision greatly exceeds that of the Hipparcos mission and the magnitude limit exceeds that investigation by several magnitudes. The Gaia mission will provide answers to many of the questions that have fascinated us for decades, such as the motion of Barnard's star (Gatewood and Eichhorn, 1973), the distance and motion of Sirius B (Gatewood and Gatewood 1978), and the distance of the Pleiades cluster (Gatewood et al., 2000). One of our areas of interest concerns the population and characteristics of stars surrounding us in space. Stellar characteristics are usually determined from binary and multiple stars. Thus, the start of this, the third paper in this series (Gatewood and Gatewood 2012, 2016).

The ongoing Gaia project released their second preliminary set of results along with estimates of the errors and the number of observations of each object in early in 2018 (https://www.cosmos.esa.int/web/gaia/dr2). The data release is based on less than two full years of observations, but the estimates of the precision are already inviting. On the other hand, by releasing the data in stages they are inviting us to study the results before all the data has been collected and fully processed. The results are preliminary, and some of it will be modified considerably before the final publication. Thus, we are at a stage where conformation of results is most useful.

Available Data and Techniques

To obtain a large sample we set our original goal on a study of all of the stars within 50 parsecs of the Sun. Because parallax errors will cause more stars to fall out of distance-limited sample than into it, we chose 51 parsecs instead of 50 for our sample limit. With this parameter, the Gaia R2 yields 80,287 stars. This is not the total number of stars in that volume. As the Gaia mission continues this number may get significantly larger or even significantly smaller.

Facing this large data download, we were happy to learn that my crusty old Fortran programs could still be used, without alteration, using the Absoft compilers f77 and even f90. With a little review of my techniques I was able to write a program that matched pairs of stars by comparing their separation, relative parallax, and relative proper motions. Looking to increase the likelihood that each pair would form a binary system we made a short survey of the separations, relative proper motions, and relative parallaxes of known binary stars. We then applied these limitations to the selection of double stars from the Gaia down load. Gaia radial velocities are available for moderately bright stars, but not for bright, or for fainter objects. They are not generally available for both the primary and secondary in our sample so no attempt was made to use them in our selection process.

To find which of these stars were already known we used the USNO WDS Catalogue of 145,404 double stars with high precision coordinates, as of its 10/18/18 update. Gaia doubles that were 20.2 arc seconds or more from any star in the WDS Catalog were designated as new discoveries. Those within that limit were examined to determine if they were the Primary system, a known companion, or a new companion. While the algorithm was not fool proof, hand checking found few errors. In examining the results one is impressed with the quality of past surveys. None of the new discoveries include secondaries brighter than the 10th magnitude nor are there any new doubles within 10 parsecs.

Facing the development of new programs and the huge number of stars in the original Gaia download we decided to reduce our distance limit to just over one half. This would yield about an eight as many double stars for this document. Instead of a limiting parallax of 0.019 arcsec we chose 0.039 arcsec. Our initial download also included objects with Gaia, Gg, magnitudes in the range 18 through 20. After reviewing the statistics of these difficult objects we decided to limit our sample to primary stars with an apparent magnitude brighter than 18. Willem Luyten once showed us two plates he was measuring on his old hand repaired and operated blink machine. Although they were taken 10 degrees or more from the galactic disk, the field was filled with images, some overlapping and others almost touching. He said that field crowding would always set a limit to what could be observed near the disk in the direction of the galactic center. Perhaps the most interesting thing about Gaia's observation of stars within 25 parsecs is how rare these very faint objects are except in the direction of the galactic disk near the galactic center. This is evidence that astronomy has indeed established the bottom of the HR Diagram.

Many of us usually think of the photometric characteristics of stars in terms of the Johnson-Cousins UBVRI system (Bessell 1990). With over a billion stars measured, Gaia measurements and magnitudes will likely be the standards for some time. We will call the three Gaia photometric bands Gg, Bg, and Rg. Crudely speaking, the Gaia green, Gg, band pass is rather like that of an unfiltered reflector and a standard CCD. The Gg band spans almost 6,000 Angstroms, including the Johnson-Cousins B, V, R, and I, and is centered near the 6,400 Angstroms line of a red light laser. The Gaia blue, Bg, band includes the B and V bands as well as approximately half of the R band. The Gaia red, Rg, band includes the longer wave lengths of the R band, all of the I band, and a little that's even longer wave lenght than that. All of the available Gaia photometry for the new doubles is given in Table 1 and Table 2. Where a value is not available it is entered as 0.000.

The Bg-Rg values of the faintest stars can reach 4 and even higher. A high Gaia red value indicates a very cool star. In a distance limited sample, such as this, the fainter stars will generally be red, unless they are white dwarfs. In the Gaia photometric system, very faint white dwarfs, with absolute mg values as faint as +16 usually have Bg-Rg values that exceed 0.8 sometimes approaching 1.8 (http://sci.esa.int/gaia/60198.).

Results

Table 1 lists the new double's J2000 RA and Dec, the angle in degrees of the line from the assumed primary to the secondary and their separation in arc seconds followed by the Gaia green band pass magnitudes of the primary and secondary star. These are followed by their proper motion in RA and Dec in mas/yr. The last two values are the primary and secondary parallax in mas (milli arc seconds).

Table 2 contains the same stars, in the same order as Table 1, listing their X and Y values in arc seconds and estimates of their standard errors in mas as well as their Bg and Rg magnitudes and the Gaia radial velocities in kilometers per sec. The X and Y values are the Standard Coordinates of the secondary star in the plane of the sky in a coordinate system formed and centered at the primary star. X and Y are the coordinates that would have been observed with a calibrated CCD on 01/01/2000. Note that the errors in X and Y are not easily transformed into similar values in polar coordinates. While polar coordinates give a better visual impression of the orbital motion of a binary star, most modern measurement and reductions are done in X and Y.

Notice that there are no actual observation dates in the Gaia data. Instead, the data has all been reduced to, and is given for, 2015.5. The reader's observations confirming these new double stars should include the dates of each observation. Such new observations will mark the start of our continued observation of the systems. The Gaia satellite will complete its mission soon leaving the continue observation of many thousands of stars to us. A good time to start is while there is still a chance to overlap our results with those of Gaia. The high precision of the Gaia observations give us an extraordinary opportunity to test and refine our observing techniques in preparation for the task that lays ahead.

Acknowledgements

This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

Thanks to Brian Mason and William Hartkopffor for answering numerous data requests. This research made extensive use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

(Text continues on page 407)

New Double Stars Within 25 Parsecs

Table 1.

Dbl	Hr	Mn	Sec	Dg	Mr	Sec	Theta	Rho	Pri G	Sec G	P pm	P pm	S pm	S pm	P pi	P pi
1	0	33	17.361	34	19	11.04	174.6394	3.1469	13.3	13.43	100	-56	82	-59	40.6	40.5
2	3	54	25.621	-9	9	30.94	153.5023	3.1766	10.54	11.88	-95	110	-96	98	47.4	47.4
3	6	35	22.267	-57	37	35.18	57.0872	1.5206	10.29	14.33	-17	53	-40	49	42.8	44.1
4	7	11	16.923	-21	17	54.66	103.8248	2.1845	13.22	13.38	-103	-64	-124	-67	50.3	50.4
5	7	30	17.51	-3	40	24.47	75.2236	199.4488	9.73	15.84	-154	44	-154	45	40.8	41
6	7	49	50.936	-3	17	19.21	265.9078	1.9446	11.55	11.92	-174	-65	-139	-37	58.8	58.8
7	8	35	12.898	-69	26	33.40	339.0264	1.2149	15	15.34	-118	65	-119	79	43.3	43.3
8	10	9	36.277	-17	50	27.87	2.5907	123.1523	10.7	10.92	84	3	85	4	46.7	46.7
9	10	31	4.541	82	33	31.27	84.2879	13.5038	5.12	12.76	-65	12	-105	37	44	44.2
10	13	36	0.026	40	24	11.88	181.5033	145.9332	13.93	14.65	39	26	36	27	42.3	42.3
11	14	19	46.721	31	37	3.73	310.0895	8.8925	12.98	15.47	99	-25	104	-21	52.6	52.6
12	14	55	59.813	-21	58	5.63	307.2401	13.4168	12	12.92	-7	-59	-6	-66	42.2	42
13	15	47	29.806	-27	55	12.11	117.9975	1.2486	12.14	13.83	96	24	98	-4	40.3	40.4
14	15	47	29.806	-27	55	12.11	37.0654	111.8905	12.14	14.74	96	24	91	30	40.3	40.8
15	15	55	46.901	-31	57	41.38	222.4897	188.6164	11.59	12.49	-126	-87	-129	-89	46.2	45.9
16	16	56	42.671	-39	8	12.75	22.8977	169.3688	8.06	11.78	51	-108	47	-113	63.7	63.6
17	16	56	42.671	-39	8	12.75	23.9608	169.199	8.06	10.38	51	-108	56	-106	63.7	63.8
18	17	12	9.199	-43	14	21.12	128.7552	591.8311	3.11	10.4	20	-285	24	-288	46	44.6
19	17	26	22.214	-24	10	31.11	188.8418	18.0551	4.03	14.56	-2	-117	13	-116	40.2	39.3
20	17	33	40.635	-42	55	43.33	22.1979	0.8619	13.23	13.24	-11	68	-11	52	42.8	44.6
21	18	8	59.136	-35	46	44.96	32.3823	3.224	13.01	13.14	-83	-96	-86	-83	45.6	45.7
22	18	9	21.379	29	57	6.17	300.682	29.1715	6.65	13.14	71	61	66	74	41	40.9
23	18	45	23.818	-32	53	38.62	68.2107	4.5216	10.44	17.14	117	49	99	39	45.7	44.9
24	18	52	43.733	36	59	25.68	160.0909	8.6133	13.41	14.1	77	34	84	28	44.3	44.4
25	19	59	25.4	34	54	25.62	128.8793	1.3986	11.5	14.6	92	12	77	13	40.3	40.1
26	21	5	32.058	6	9	15.47	166.0123	5.0952	11.45	14.88	27	45	37	49	44.3	44.5
27	22	56	4.365	75	56	22.33	19.8557	242.3707	7.99	13.68	34	-36	34	-36	40.5	40.8
28	23	17	25.752	-58	14	8.71	110.1853	4.7167	3.81	12.03	-7	86	-35	57	42.3	41.1
29	23	36	18.274	-48	35	17.07	327.9683	334.691	9.46	14.93	-126	-24	-132	-24	39.9	40.5

New Double Stars Within 25 Parsecs

Table 2.

Dbl	X	Xe	Y	Ye	Bg P	Rg P	Bg S	Rg S	RV p	RV s
1	0.294	0.07191	-3.13313	0.07013	15.02	12.03	15.16	12.15	0	0
2	1.41728	0.04297	-2.8429	0.04166	11.68	9.502	13.32	10.69	2.306	0
3	1.27651	0.03137	0.82622	0.04177	11.29	9.318	0	0	31.21	0
4	2.12118	0.03246	-0.52198	0.04423	14.91	11.86	15.09	12.09	0	0
5	192.8528	0.05042	50.86893	0.04496	10.66	8.809	18.43	14.37	46	0
6	-1.93969	0.09782	-0.13877	0.07838	13.19	10.28	13.48	10.63	0	0
7	-0.43486	0.20189	1.13442	0.2115	16.87	13.19	0	0	0	0
8	5.56651	0.04968	123.0264	0.05162	11.85	9.667	12.14	9.867	-10.48	-11.26
9	13.43672	0.35732	1.34403	0.34515	5.366	4.828	14.37	11.52	0	0
10	-3.8286	0.04703	-145.883	0.05953	15.82	12.62	16.77	13.28	0	0
11	-6.80312	0.06193	5.72662	0.07306	14.65	11.74	18.19	14	0	0
12	-10.6812	0.07134	8.11927	0.05805	13.36	10.87	14.5	11.7	0	0
13	1.10245	0.14329	-0.58612	0.06667	13.4	10.94	0	0	0	0
14	67.43931	0.14329	89.28283	0.06667	13.4	10.94	17.01	13.35	0	0
15	-127.402	0.08003	-139.086	0.0423	12.96	10.47	14.17	11.25	0	0
16	65.89912	0.06886	156.0227	0.06209	8.758	7.297	13.49	10.53	-8.582	0
17	68.71371	0.06886	154.618	0.06209	8.758	7.297	11.77	9.248	-8.582	0
18	461.5264	0.57039	-370.483	0.5009	3.588	2.891	11.5	9.391	0	-22.88
19	-2.77519	0.39879	-17.8405	0.34169	4.253	3.864	16.25	13.21	0	0
20	0.32563	0.38997	0.79801	0.30349	14.24	11.33	14.23	11.34	0	7.986
21	1.72666	0.09509	2.72263	0.08443	14.49	11.81	14.63	11.94	0	0
22	-25.0879	0.02501	14.88541	0.03014	6.997	6.188	12.99	13.34	-14.55	0
23	4.19856	0.05678	1.67839	0.05783	11.54	9.433	18.11	15.41	-6.439	0
24	2.93309	0.03504	-8.09855	0.04228	14.82	12.25	15.73	12.87	0	0
25	1.08876	0.02586	-0.87787	0.03261	12.61	10.45	0	0	0	0
26	1.23158	0.06593	-4.94414	0.04708	12.88	10.31	17.07	13.48	0	0
27	82.32176	0.0378	227.9621	0.03607	8.497	7.372	15.38	12.42	-9.309	0
28	4.42701	0.2535	-1.62754	0.29814	4.144	3.543	11.29	10.48	0	0
29	-177.516	0.03075	283.736	0.04318	10.33	8.567	17.17	13.53	-0.782	0

(Continued from page 404)

References

Bessell, M. S. 1990, *PASP*, **102**, 1181.

Gatewood; Eichhorn, H. 1973, *AJ*, **78.**

Gatewood, G. D., & Gatewood, C. V. 1978, *ApJ*, **225**, 191.

Gatewood, G.D. and Gatewood, C.V. 2012, *JDSO*, **8**, 335-339.

Gatewood, G.D. and Gatewood, C.V. 2016, *JDSO*, **12**, 580-585.

Gatewood, G., de Jonge, J. K. & Han, I. 2000, *ApJ*, **533**, 938.

https://www.cosmos.esa.int/web/gaia/dr2

http://sci.esa.int/gaia/60198-gaia-hertzsprung-russell-diagram/

http://sci.esa.int/gaia/60198