The Sweet Sixteen: Measures for Some Likely Bound Pairs

Glenn M. Thurman
Cuyamaca College, El Cajon, California

Abstract: Measures for sixteen doubles are presented. CCD images were obtained using an LX-200 16-inch telescope. MPO Canopus was used for reduction and calculation of separation and position angle. Cartesian plots of secondary motion, derived from present and historical measures, are presented.

1. Introduction

The goal of measuring double stars is the detection of orbital motion. Orbit solutions are the key to stellar masses, which in turn are crucial to stellar evolution theory.

Sixteen double stars, selected for their high probability of being bound pairs, were observed during 2021. Measures are reported here. Cartesian plots of secondary motion, derived from present and historical measures, are also presented.

2. Selection of the Pairs

Sixteen doubles were chosen (indirectly) from the Washington Double Star Catalog (WDS), Mason (2017), via Harshaw's (2018) Excel spreadsheet. The spreadsheet is a WDS extraction from the Gaia DR2, i.e., Gaia DR2 observations of WDS objects.

The sixteen pairs observed were chosen for likelihood of being physical, based on data in Harshaw's table -- most importantly parallax/distance, proper motion and radial velocity. For each pair Harshaw calculates a probability of being physical. My conclusions regarding physicality, based on inspection of the data, invariably agree with Harshaw. The Gaia data is worth consulting before selecting targets for observation.

Given in Table 1 are the WDS identifiers of the sixteen double stars observed. Also presented are the WDS Discoverer Designation and the WDS coordinates.

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	WDS Identifier	Discoverer Designation	WDS Coordinates
1	06175-1537	GAL 398	06:17:28.17 -15:38:35.1
2	06183+6212	STF 866 AB	06:18:16.02 +62;11:51.7
3	06243-1258	STF 903	06:24:20.58 -12:57:43.0
4	09000+1016	HJ 5475	08:59:57.37 +10:16:18.9
5	09033-3336	HJ 4166 A-BC	09:03:16.11 -33:36:02.3
6	09125+2354	POU 3032	09:12:28.19 +23:54:39.3
7	09368+1914	HJ 468	09:36:46.16 +19:14:04.4
8	10390+5104	UC 157	10:39:01.53 +51:04:24.8
9	10420-3638	LDS 314	10:41:51.83 -36:38:00.1
10	11136-1558	ARG 24	11:13:35.48 -15:57:50.7
11	11139+2159	CBL 48	11:13:54.31 +21:58:33.3
12	11141-1122	UC 2106	11:14:05.39 -11:21:59.7
13	11145+5733	STI 2263	11:14:27.05 +57:33:23.2
14	12087-2804	SKF 1914	12:08:40.74 -28:041:8.5
15	13024-1729	HJ 2630	13:02:26.89 -17:29:23.4
16	13581+4255	LDS 4422 AB	13:58:08.17 +42:54:12.3

Table 1. WDS Identifier, for the Primary Star of Each Double.

3. Observations and Reduction

The observations were made using a Meade LX200 16-inch f/10 reflecting telescope located at Gregory T. Thurman Memorial Observatory, in the foothills of East County San Diego, California, situated at about 2600 feet, under moderately dark skies.

Gregory T. Thurman Memorial Observatory.

The CCD imaging was done using an SBIG STF-8300M monochrome camera, with a KAF-8300 CCD and 1.4-micron square pixels. Images were taken through either a Johnson-Cousins V filter or I_C filter (of the Johnson-Cousins $UBVR_CI_C$ system). All images were flat-fielded and dark subtracted. The double star astrometry utility of the MPO Canopus software was used for the measures of separation and position angle. MPO Canopus "…provides a unique tool that directly computes the separation and position angle of any selected pair of stars (including the required precession calculation…)" Buchheim (2008).

4. Measures

Table 2 lists the measures for the sixteen pairs observed, each measure being the average of some number of independent observations (separation or position angle). Also listed in the table are the number of observations obtained for each double, the Julian Epoch, and the Standard Error of the Mean (SEM) for the averaged measures (separation or position angle).

Equation 1 was used to calculate the standard error of the mean (SEM) for the averaged observations (separation or position angle).

Equation 1.

$$SEM = \frac{\sigma}{\sqrt{N}} ,$$

where N is the number of observations averaged to give a measure of separation or position angle, and $\boldsymbol{\sigma}$ is the standard deviation (SD) of the N observations.

Table 2. Measures of Separation and Position Angle for the sixteen Pairs.

	WDS Catalog	Discovery Designation	No. of Obs.	Julian Epoch	Separation (Arcsecs)	SEM	Position Angle (Deg.)	SEM
1	06175-1537	GAL 398	11	2021.14	10.32	0.024	276.92	0.049
2	06183+6212	STF 866 AB	8	2021.14	17.91	0.0062	195.60	0.022
3	06243-1258	STF 903	13	2021.17	23.11	0.020	295.02	0.029
4	09000+1016	HJ 5475	8	2021.029	16.82	0.013	252.04	0.040
5	09033-3336	HJ 4166 A-BC	13	2021.17	13.63	0.014	152.85	0.035
6	09125+2354	POU 3032	10	2021.05	14.29	0.016	113.50	0.060
7	09368+1914	HJ 468	12	2021.04	15.91	0.0028	304.94	0.023
8	10390+5104	UC 157	11	2021.15	17.60	0.014	295.06	0.028
9	10420-3638	LDS 314	16	2021.17	17.18	0.012	303.09	0.034
10	11136-1558	ARG 24	12	2021.18	17.60	0.0074	350.37	0.026
11	11139+2159	CBL 48	13	2021.18	15.54	0.012	189.81	0.037
12	11141-1122	UC 2106	5	2021.06	19.19	0.023	147.06	0.059
13	11145+5733	STI 2263	16	2021.06	11.14	0.0073	269.15	0.025
14	12087-2804	SKF 1914	7	2021.04	18.78	0.0094	265.40	0.026
15	13024-1729	HJ 2630	11	2021.10	13.65	0.0086	98.70	0.027
16	13581+4255	LDS 4422 AB	13	2021.11	18.44	0.0089	102.53	0.033

5. Historical Data

Historical measures (WDS catalog) of separation and position angle for the pairs measured in this work were provided by Brian Mason.

Presented in Appendix 1 are Cartesian plots of the motion of the secondary star with respect to the primary, using the combined data, present and historical. Two plots for each pair are presented. The X and Y axis scales are equal for each graph. The "Zoom OUT" graphs give a small-scale view of the data and the location of the primary, represented by a cross. The "Zoom IN" graphs give a large-scale view of the data, with the primary position far off the graph. For each Cartesian plot, the x and y coordinates are given by Equations 2 and 3:

Equation 2. $x = \varrho \sin PA$

Equation 3. $y = - \varrho \cos PA,$

where ϱ (rho) equals the separation in arcseconds, PA equals the position angle in degrees, East is in the positive x direction, and North is in the negative y direction.

For haphazardly chosen doubles, such as those presented by Thurman (2021), the data in some cases show a long, linear trend, compared to the clumpy look of the data presented here. The Thurman (2021) doubles are likely not bound, moving through space independently, and the resulting graph is just a picture of rectilinear motion in some cases, or merely observational noise in others. In his spreadsheet, Harshaw calculates a high probability that the pairs in this study are bound. However, signs of orbital motion are not apparent in the plots, nor are signs of rectilinear motion, for that matter. Just measurement noise. Historical data typically spans about a century, and the periods of visual binaries can easily be hundreds to thousands of years, so even if the pairs are physical, it will be a while before we notice it.

6. Conclusion

Measures of separation and position angle were obtained and presented for sixteen double stars, using a 16-inch reflector for observations, and MPO Canopus for reduction. Cartesian plots of motion of the secondary star were also presented.

MPO Canopus gives results which compare favorably with recent historical data. One weakness in its method and similar methods is that catalog stars are used to calibrate the images, thus compounding image measurement errors with errors in catalog positions.

The best chance for detecting orbital motion (besides looking up doubles with published orbits) is to pick targets at close range and small angular separation. That will be the goal of future work at Gregory T. Thurman Memorial Observatory.

7. Acknowledgement

Thanks to Brian Mason for prompt delivery of requested WDS historical data.

8. References

1. Buchheim, R.K., “CCD Measurements of Visual Double Stars,” The Society for Astronomical Sciences 27th Annual Symposium on Telescope Science. Held May 20-22, 2008 at Big Bear Lake, CA. Published by the Society for Astronomical Sciences., p.13.
2. Mason, B., 2017, “The Washington Double Star Catalog”, Astrometry Department, U.S. Naval Observatory.
3. Thurman, G.M., 2021, “The NINE: A Sabbatical Serving of Doubles,” *JDSO*: 17(1), 11 – 20.

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Appendix 1.

Motion of Secondary, Cartesian Coordinates

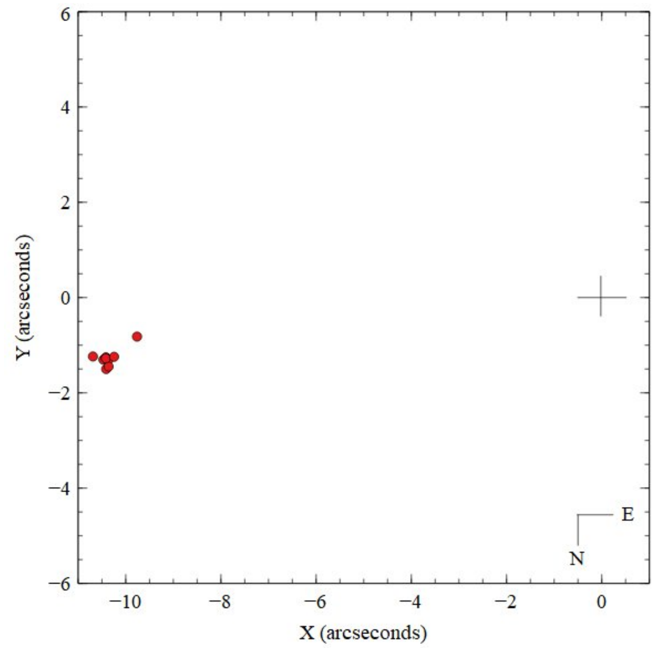

Figure 1a. WDS 06175-1537 Y vs. X, Zoom OUT.

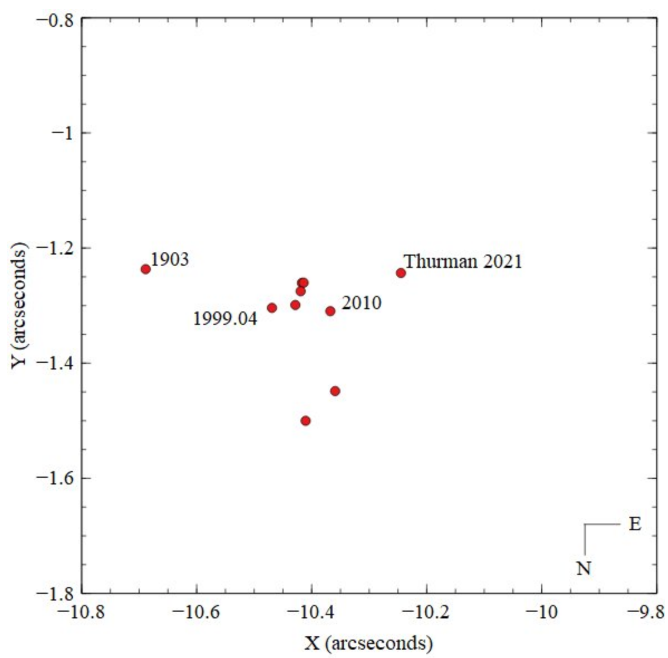

Figure 1b. WDS 06175-1537 Y vs. X, Zoom IN.

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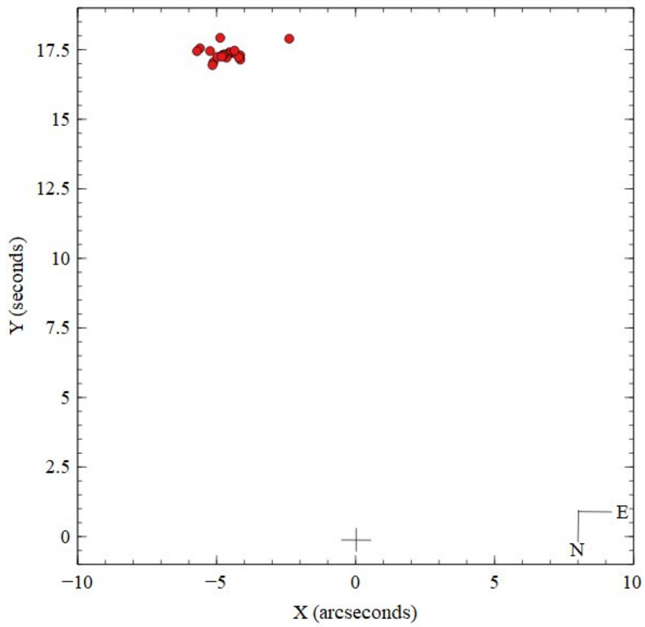

Figure 2a. WDS 06183+6212 Y vs. X, Zoom OUT.

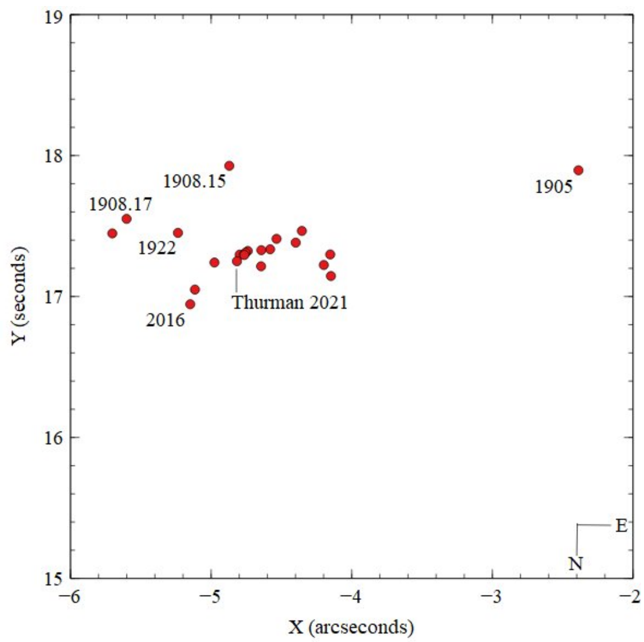

Figure 2b. WDS 06183+6212 Y vs. X, Zoom IN.

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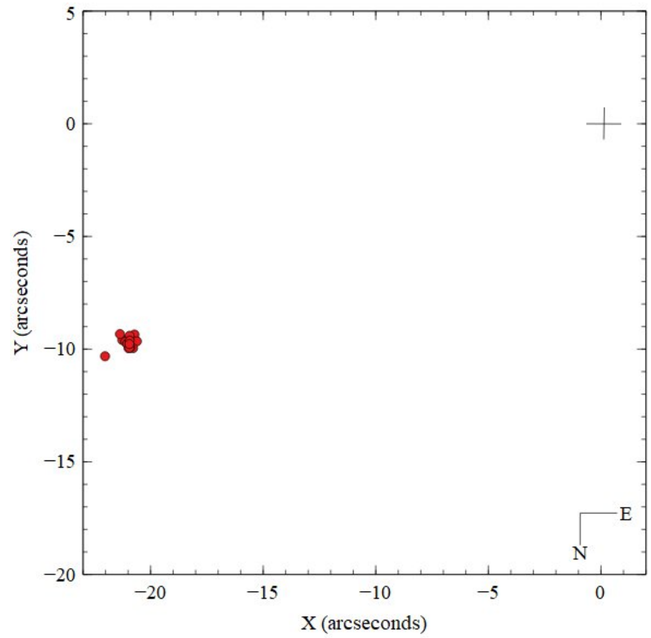

Figure 3a. WDS 06243-1258 Y vs. X, Zoom OUT.

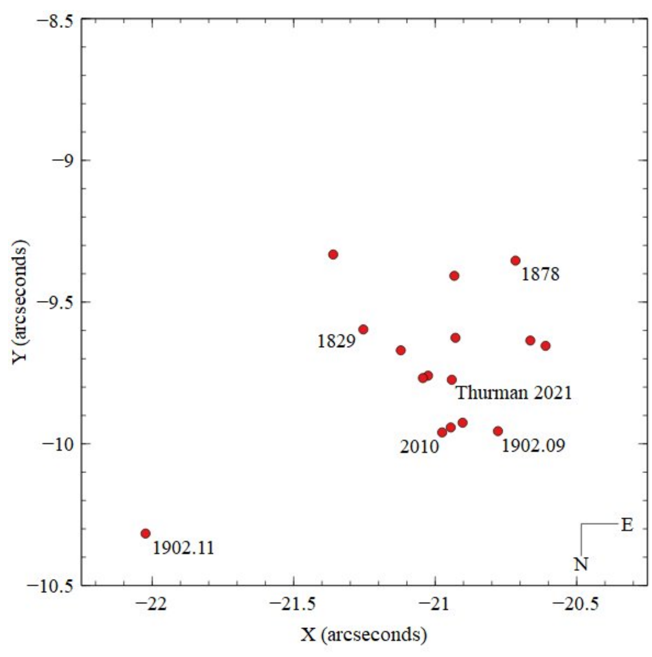

Figure 3b. WDS 06243-1258 Y vs. X, Zoom IN.

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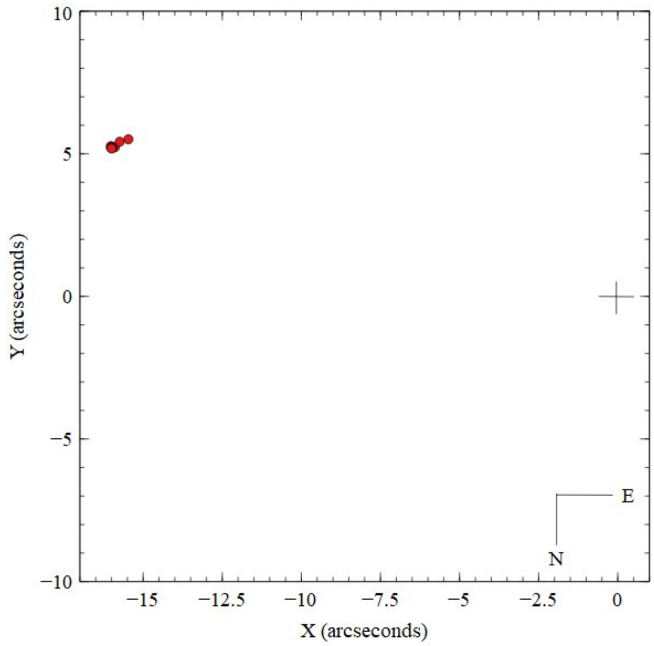

Figure 4a. WDS 09000+1016 Y vs X, Zoom OUT.

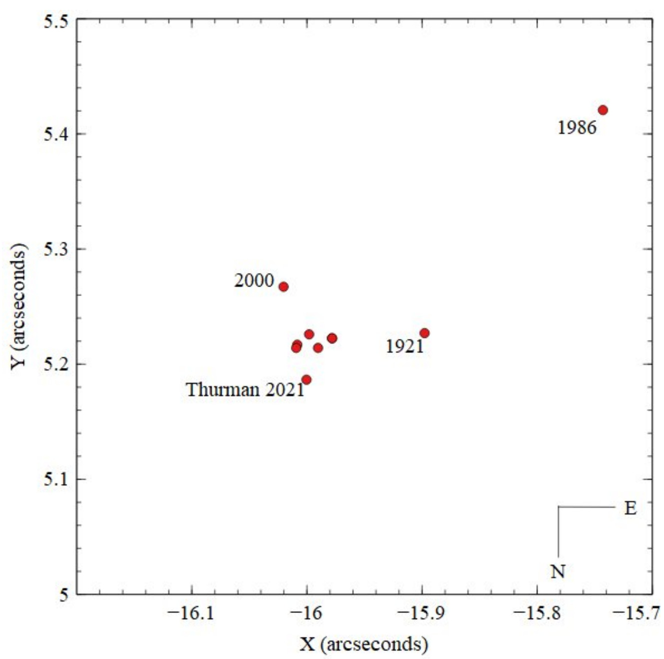

Figure 4b. WDS 09000+1016 Y vs. X, Zoom IN.

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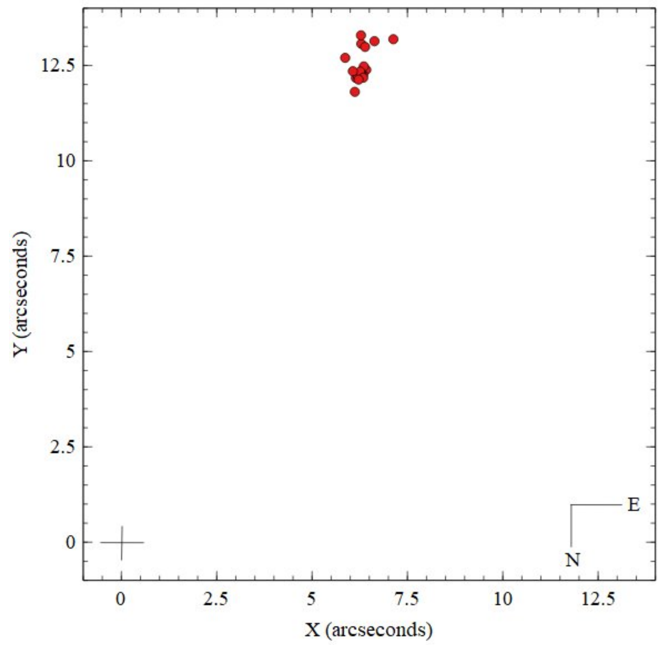

Figure 5a. WDS 09033-3336 Y vs. X, Zoom OUT.

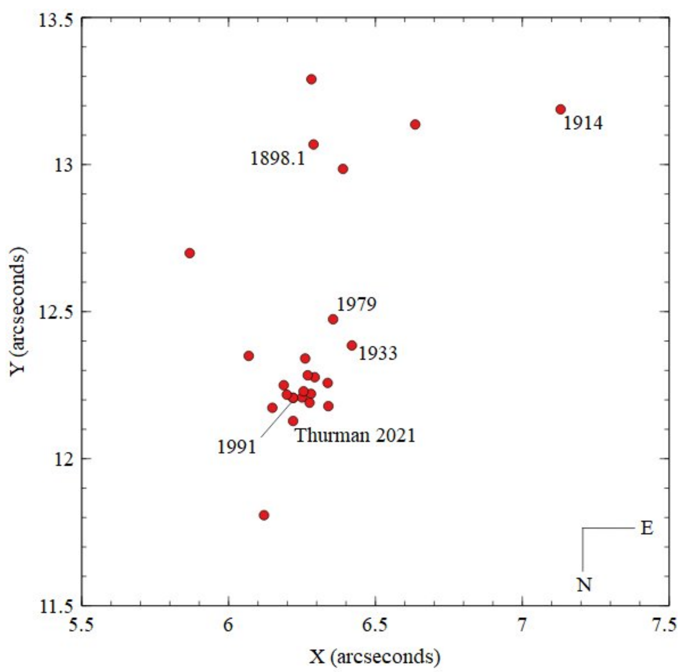

Figure 5b. WDS 09033-3336 Y vs X, Zoom IN.

The Sweet Sixteen: Measures for Some Likely Bound Pairs

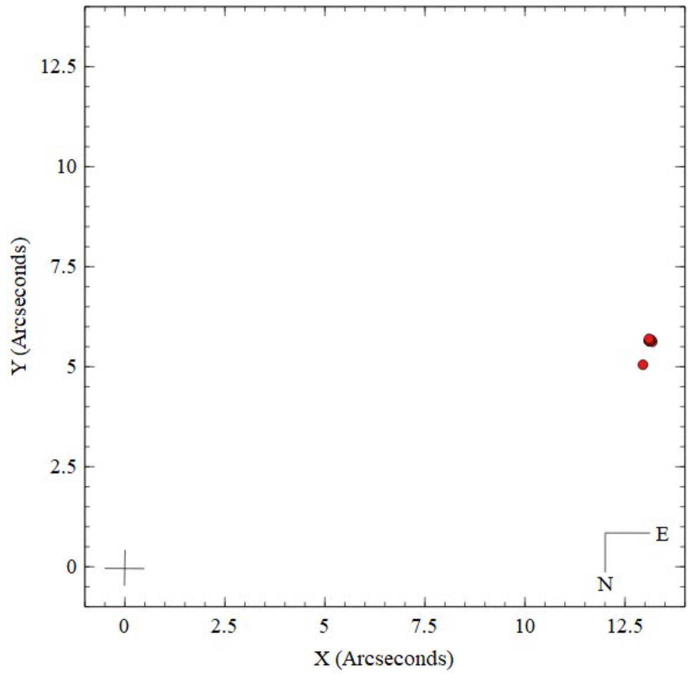

Figure 6a. WDS 09125+2354 Y vs. X, Zoom OUT.

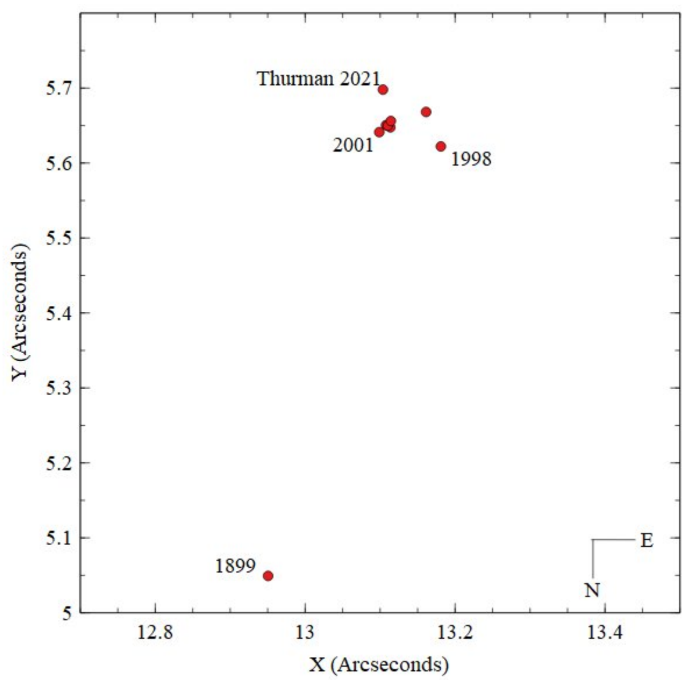

Figure 6b. WDS 09125+2354 Y vs. X, Zoom IN.

The Sweet Sixteen: Measures for Some Likely Bound Pairs

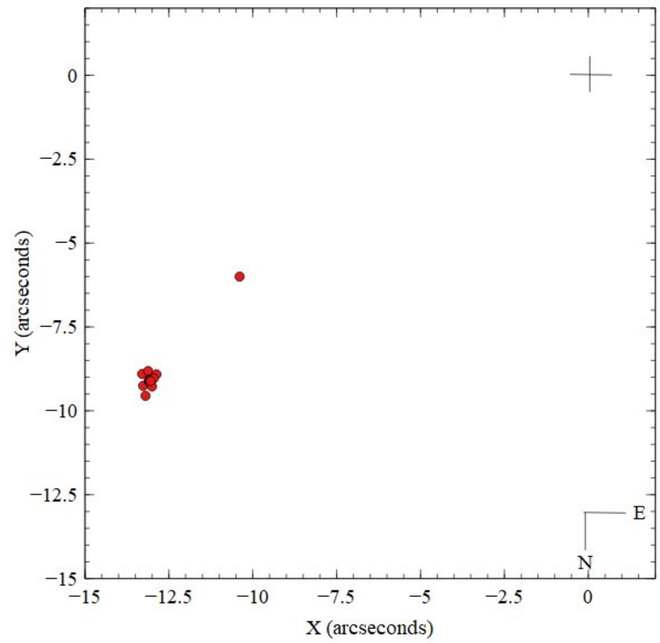

Figure 7a. WDS 09368+1914 Y vs. X, Zoom OUT.

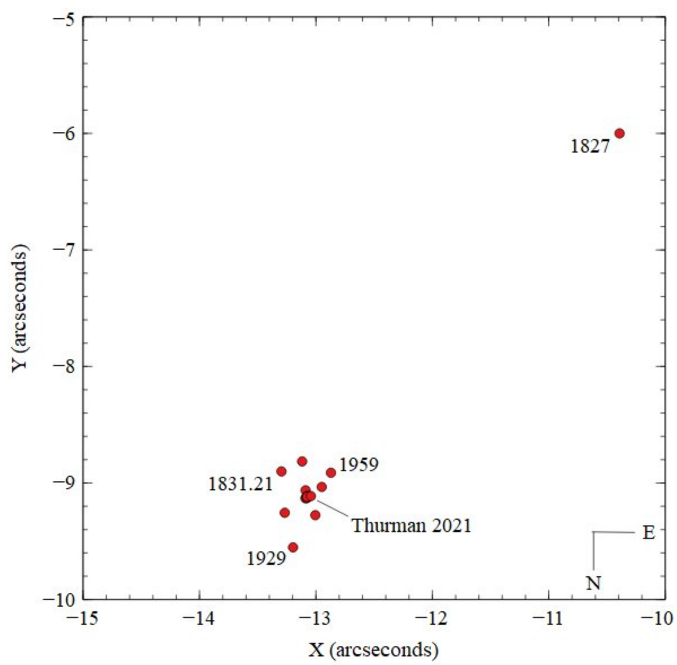

Figure 7b. WDS 09368+1914 Y vs. X, Zoom IN.

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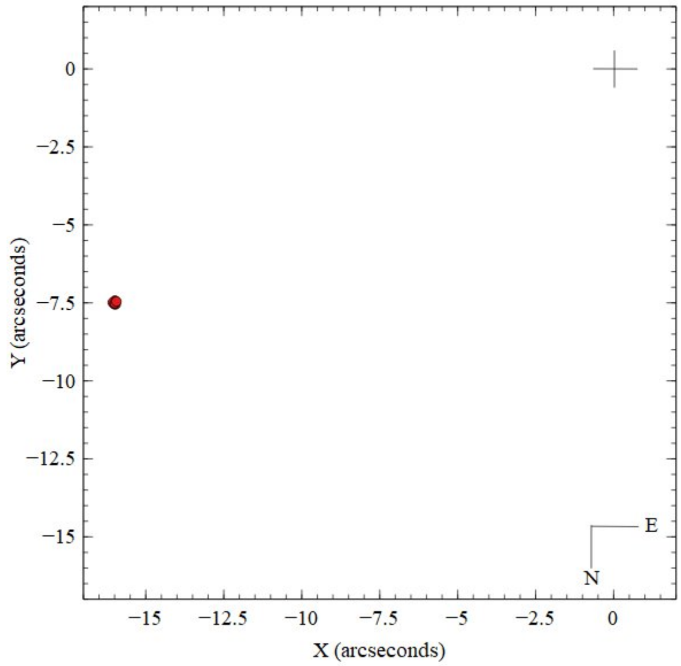

Figure 8a. WDS 10390+5104 Y vs. X, Zoom OUT.

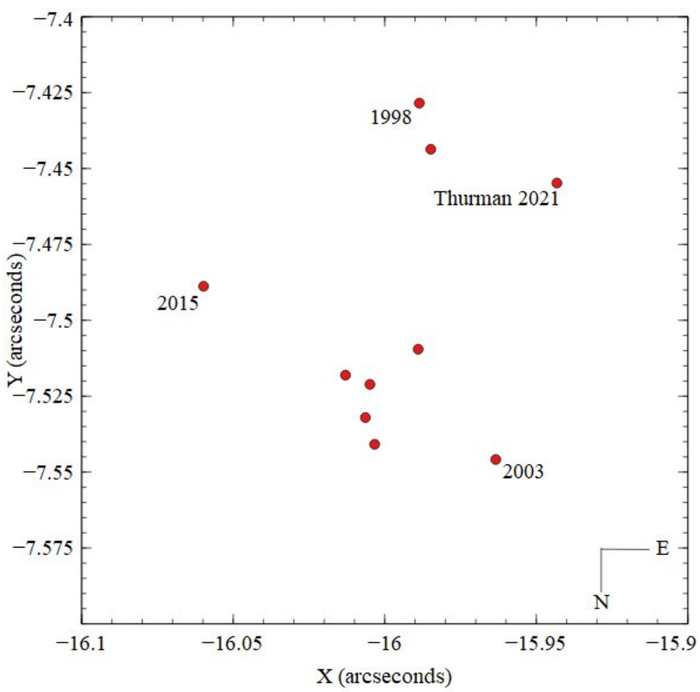

Figure 8b. WDS 10390+5104 Y vs. X, Zoom IN.

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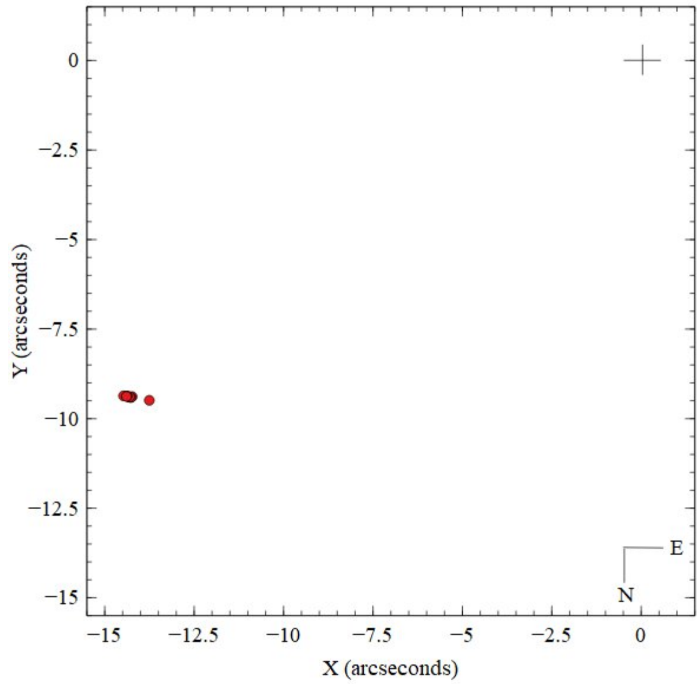

Figure 9a. WDS 10420-3638 Y vs. X, Zoom OUT.

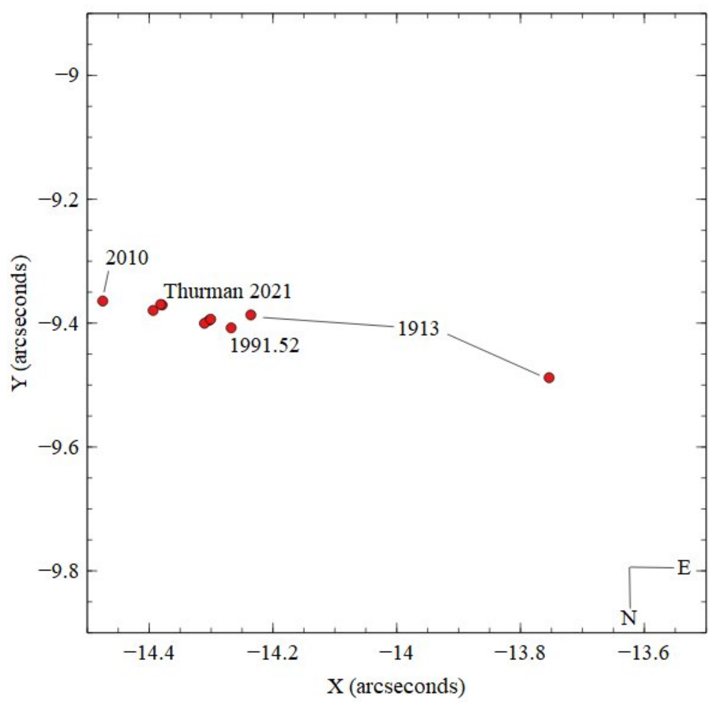

Figure 9b. WDS 10420-3638 Y vs. X, Zoom IN.

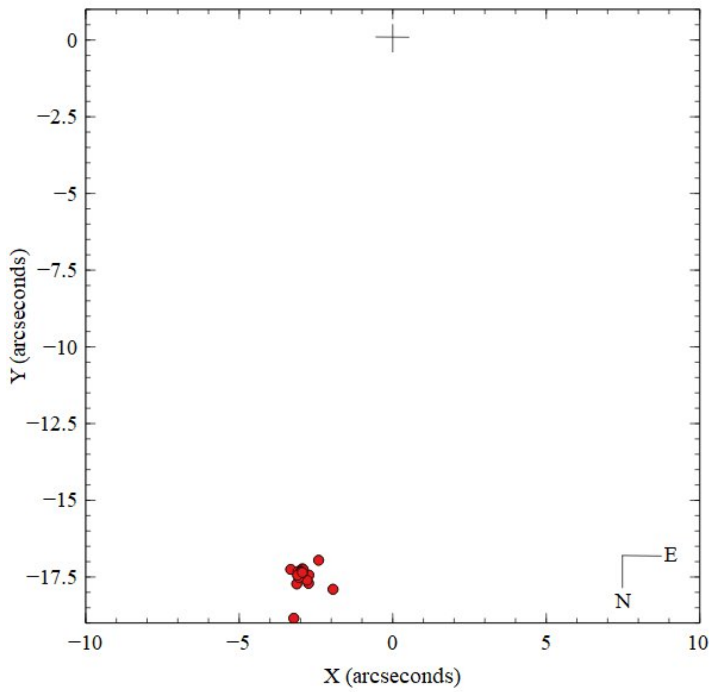

Figure 10a. WDS 11136-1558 Y vs. X, Zoom OUT.

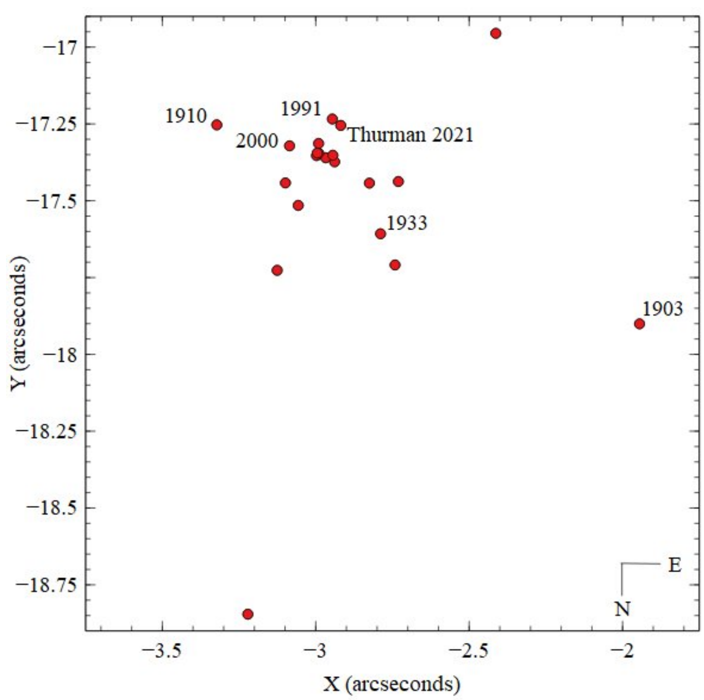

Figure 10b. WDS 11136-1558 Y vs. X, Zoom IN.

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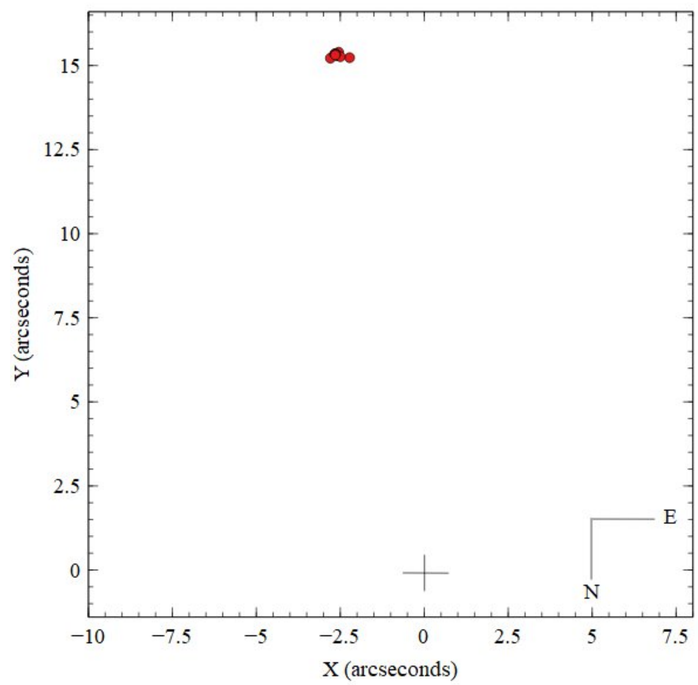

Figure 11a. WDS 11139+2159 Y vs. X, Zoom OUT.

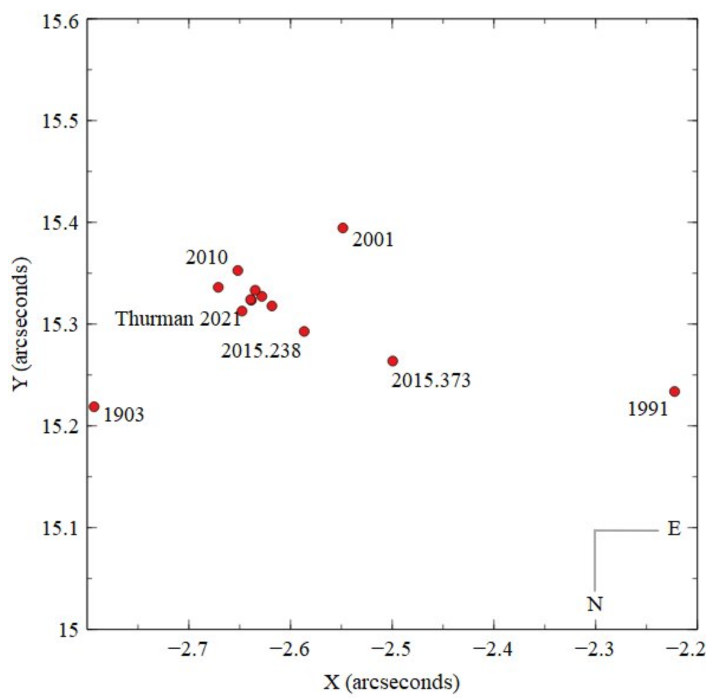

Figure 11b. WDS 11139+2159 Y vs. X, Zoom IN.

The Sweet Sixteen: Measures for Some Likely Bound Pairs

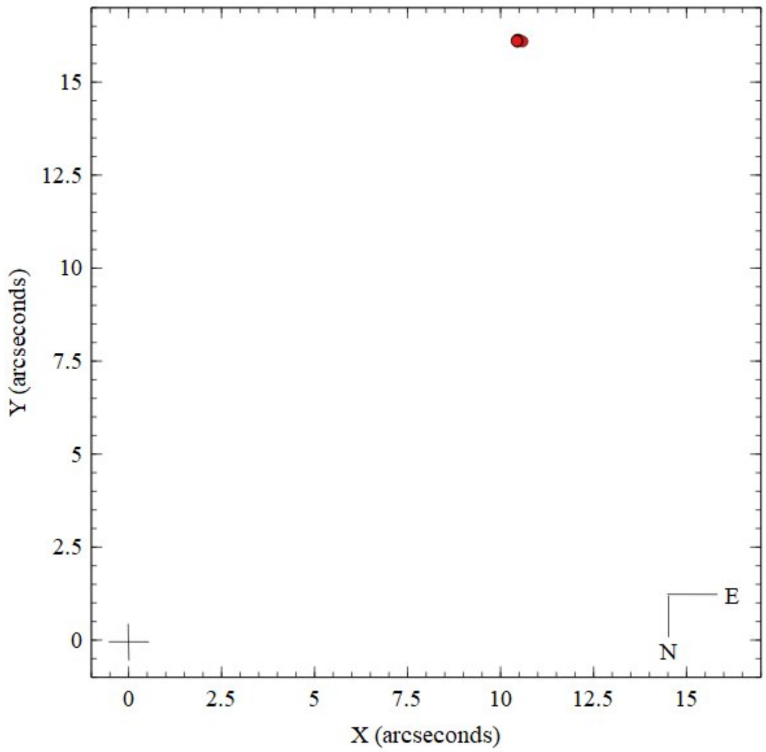

Figure 12a. WDS 11141-1122 Y vs. X, Zoom OUT

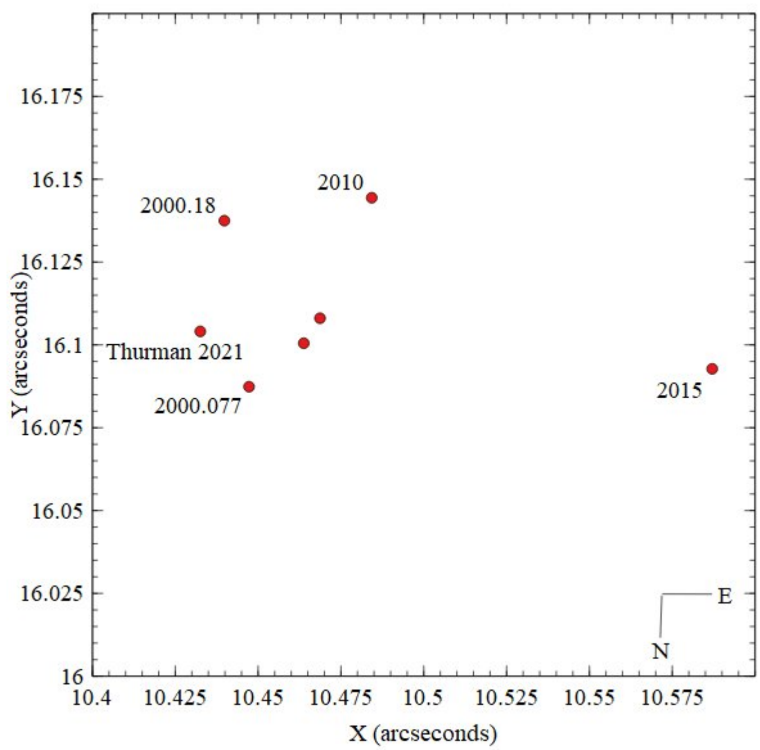

Figure 12b. WDS 11141-1122 Y vs. X, Zoom IN.

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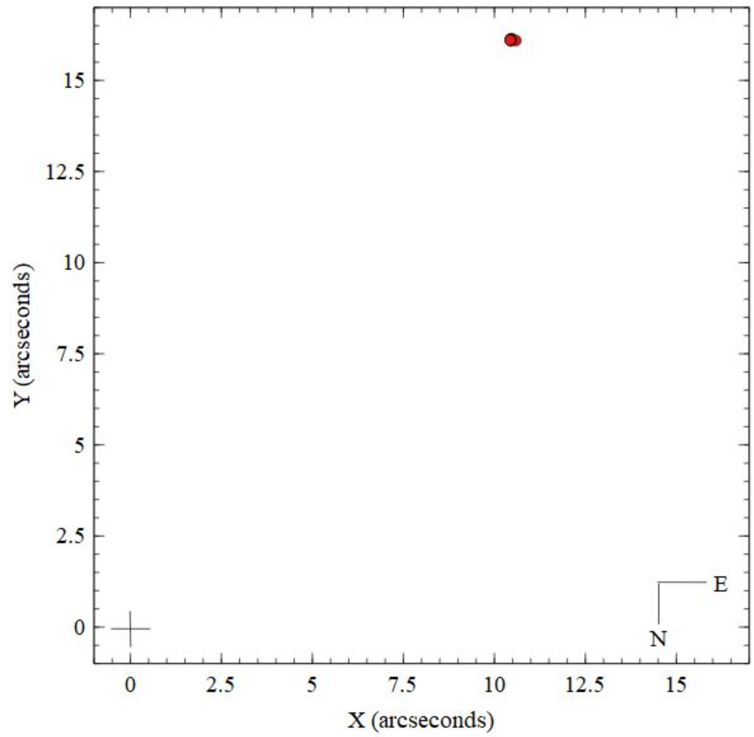

Figure 13a. WDS 11145+5733 Y vs. X, Zoom OUT.

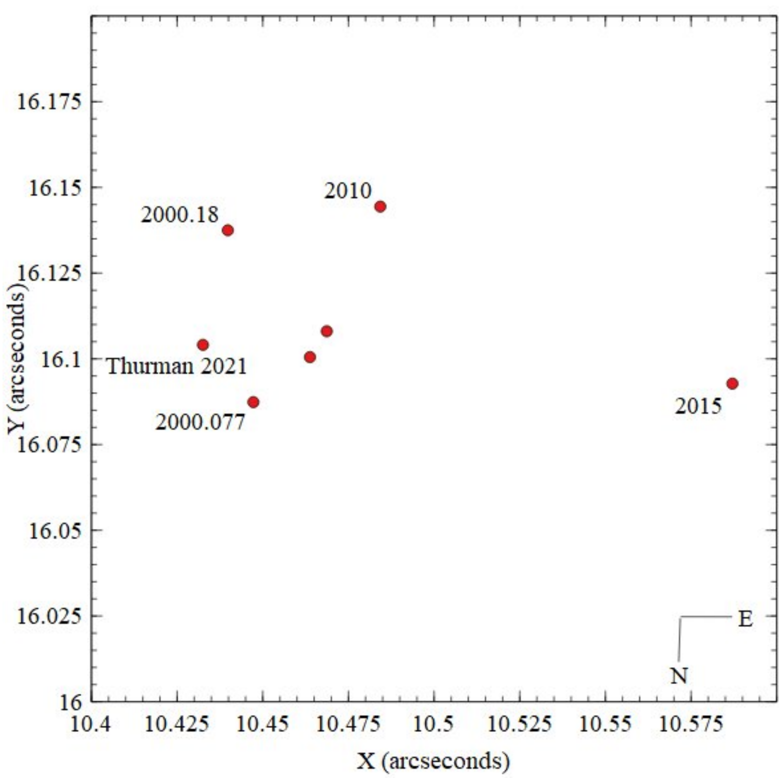

Figure 13b. WDS 11145+5733 Y vs. X, Zoom IN.

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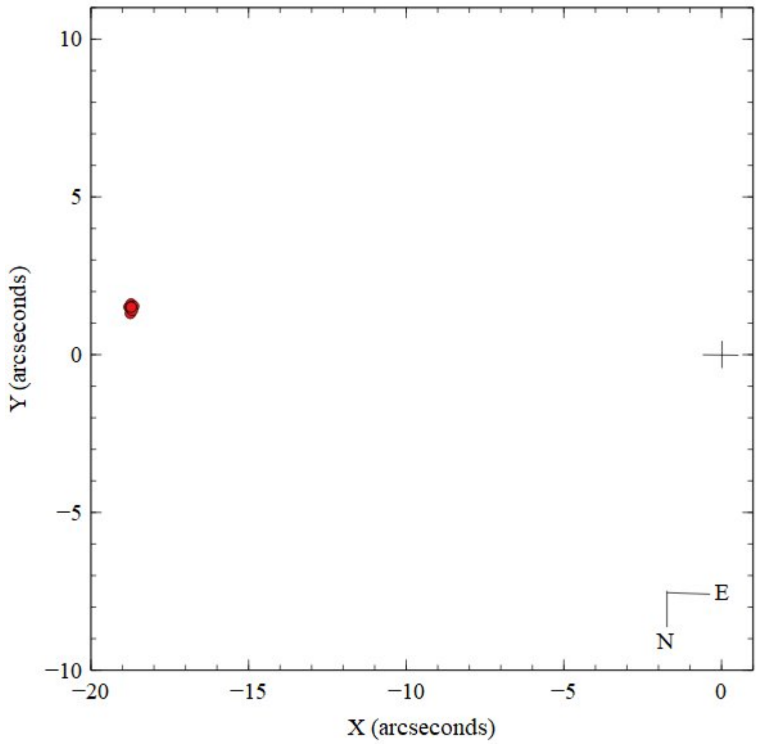

Figure 14a. WDS 12087-2804 Y vs. X, Zoom OUT.

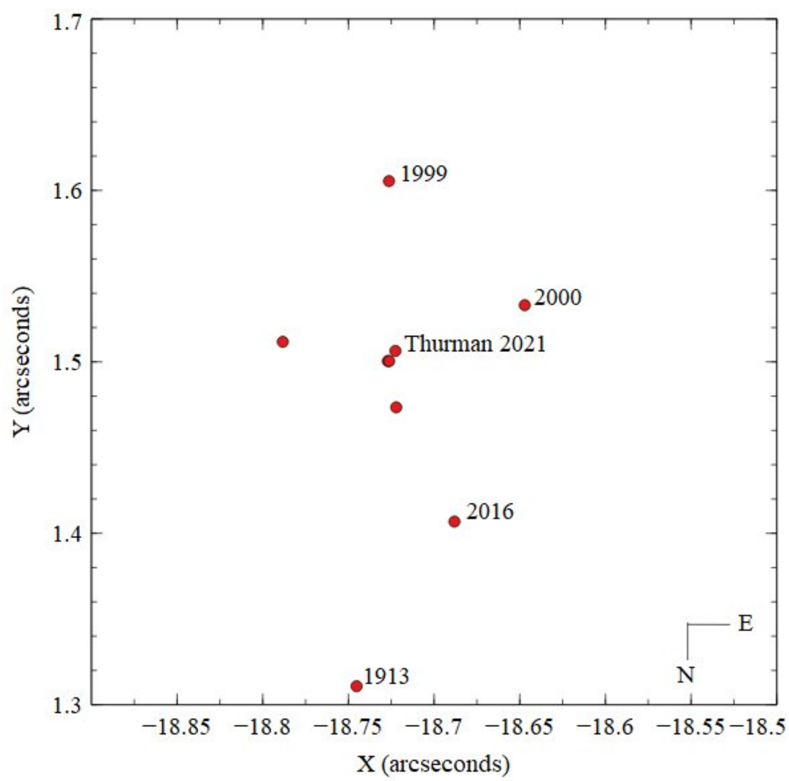

Figure 14b. WDS 12087-2804 Y vs. X, Zoom IN.

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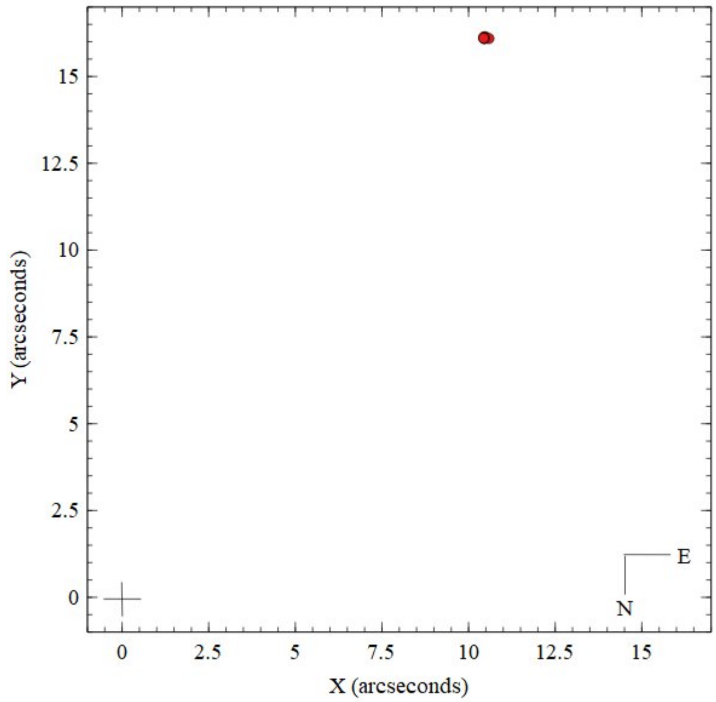

Figure 15a. WDS 13024-1729 Y vs. X, Zoom OUT.

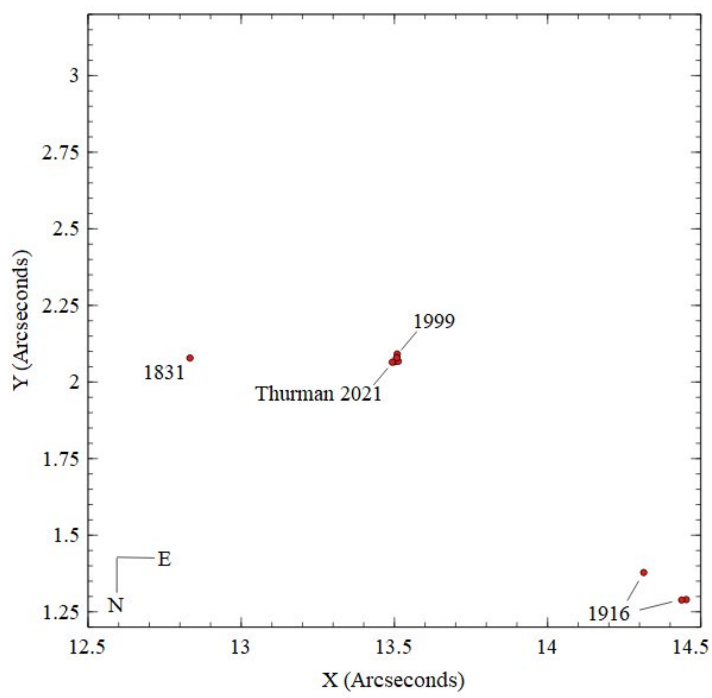

Figure 15b. WDS 13024-1729 Y vs. X, Zoom IN.

The Sweet Sixteen: Measures for Some Likely Bound Pairs

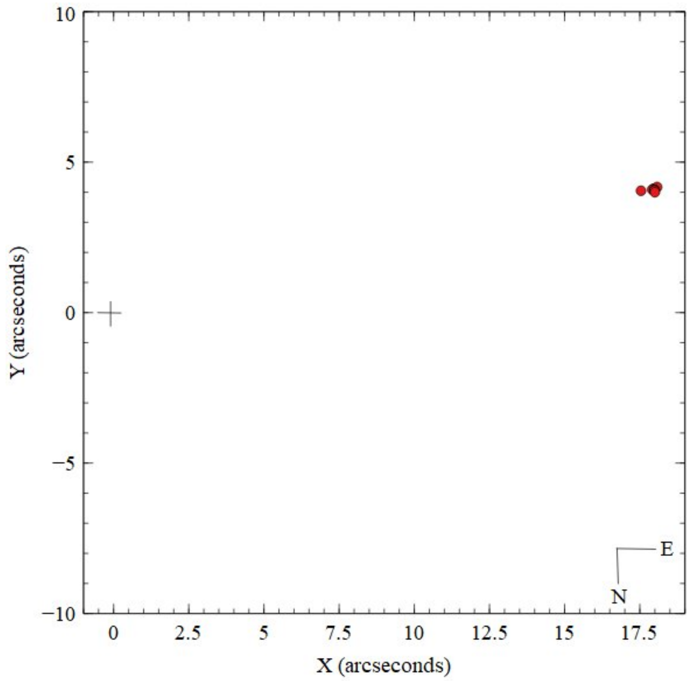

Figure 16a. WDS 13581+4255 Y vs. X, Zoom OUT.

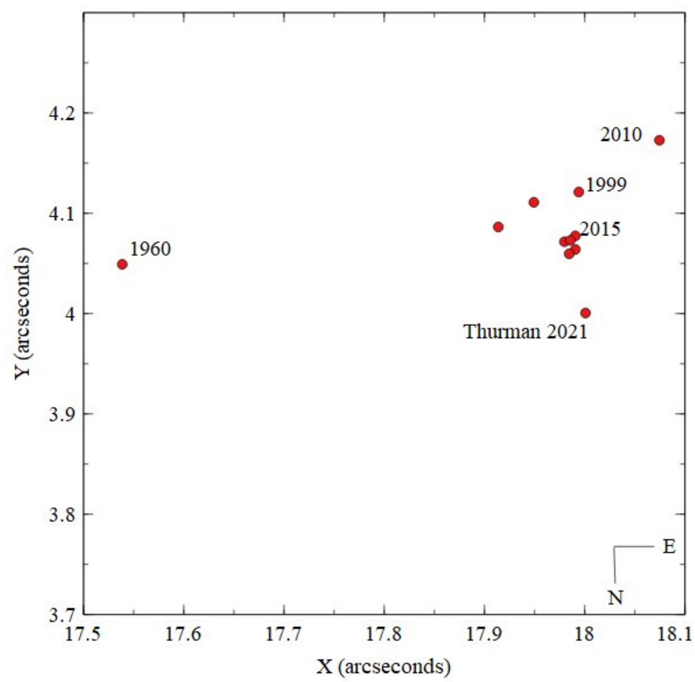

Figure 16b. WDS 13581+4255 Y vs. X, Zoom IN.