International Speckle Interferometry Collaboration

Eric Weise[1], Yuan-Yuan Ding[2], Chaoyan Wang[2], and Russell M. Genet[3,4,5,6]

1. University of California, San Diego
2. Shanghai Astronomical Observatory
3. California Polytechnic State University, San Luis Obispo
4. Concordia University, Irvine, California
5. Cuesta College, San Luis Obispo, California
6. University of North Dakota, Grand Forks

Abstract Part of a binational cooperation, astronomers from China and the United States observed ten double stars using speckle interferometry. These doubles are STF2021B, STF2140AB, STF2161AB, STF2245AB, STF2264, STF2280AB, STF2486AB, STF2578AB, STF2588A,BC, and STF2789AB. Of these doubles, there are two, STF2616AB and STF2245AB, whose past observations appear to make a short arc, but do not have an orbit published in the sixth Catalog of Orbits of Visual Binary Stars.

Introduction

In the summer of 2013 Yuan-Yuan Ding and Chaoyan Wang, astronomers at the Chinsese state run Shanghai Astronomical Observatory, came to California. In between visits to the California Institute of Technology and the Center for Adaptive Optics at the University of California, Santa Cruz, Ding and Wang spent several days in San Luis Obispo as the guests of Russell Genet and Eric Weise. Seizing the opportunity to form an international collaboration, the group decided to make speckle observations at the Orion Observatory in Santa Margarita, CA (Figure 1).

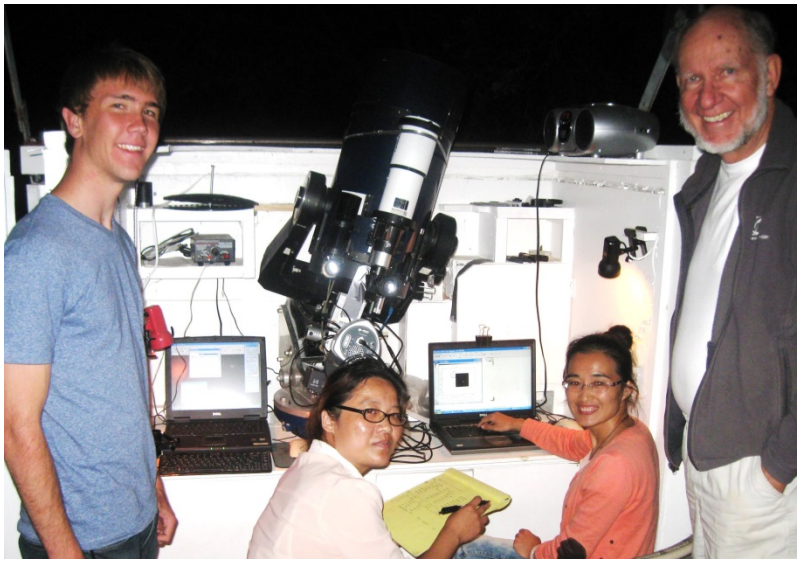

Figure 1. The observers pose in front of their instrument. From left to right: Eric Weise, Chaohan Wang, Yuan-Yuan Ding, and Russell Genet.

Ding and Wang had originally planned on attending the Maui International Double Star Conference, which was held in February 2013 at the University of Hawaii, Institute for Astronomy (Genet 2013b). Unfortunately, their visas were not approved until after the conference. Despite not making it in person, their poster was presented at the conference and Ding's paper was accepted for the proceedings of the conference (Ding 2015).

Equipment and Methods

The Orion Observatory is run by Genet near his home in Santa Margarita, CA. Observations were made using the 10 inch, f/10, equatorial mounted, internally baffled Meade telescope driven by a Sidereal Technology control system. Observations of the double stars were made using Genet's custom speckle camera (Genet 2013a). This system uses an Andor Luca-S camera capable of taking the short exposures and seeing the speckles at low light. A x2 Barlow lense was used to increase the magnification. The speckle images were saved in a .FITS cube which were analyzed using Reduc, a double star reduction program developed by Florent Losse. More details on the camera and the aspirations of Genet's speckle program can be found in his paper (Genet et al. 2013c).

Calibration Methods

The pixel scale (E) and the camera angle (Δ) were found using two different methods (see Table 1). In Method 1, E and Δ were found separately. Δ was found using the drift method on a single star: the telecope tracking was turned off and the star was allowed to drift through the field of view as the camera took a series of images. This series of images was saved into a FITS cube and analyzed using the "Synthetic Drift Analysis" option in Reduc. E was determined using a slit mask. The slit mask had a spacing of d=0.673 inches or 1.71×10^7 nanometers. An Hα filter was used, giving a wavelength of λ=656nm. The angular separation of the diffraction peaks at the focus of the telescope was found using equation 1 (Maurer 2012):

$$\frac{206{,}265\lambda}{d} \qquad \textit{Eq. 1}$$

A single star was observed through the slit mask using speckle imaging; 2,000 images, each exposed for 15 milliseconds, were taken per observation, and an autocorrelogram made and analyzed using Reduc. The slit mask was rotated by an arbitrary angle after each observation in order to reduce any systematic bias in the camera orientation.

In Method 2 a sufficiently static double star was observed through a Sloan R' filter. Each observation yielded a FITS cube comprised of 2,000 images taken with an exposure time of 15 milliseconds. Then, E and Δ were found using the calibration mode of Reduc. The values of θ and ρ entered into Reduc were the averages of the observations from the ten most recent entries in the Washington Double Star Catalog.

				Δ (˚)			E (a.s./pixel)		
Star	Method	Epoch	#obs	Δ	Std Dev	Std Err	E	Std Dev	Std Err
STF2486 AB	2	B2013.629	6	-2.8742	0.3558	0.1453	0.2568	0.0009	0.0004
Deneb	1	B2013.629	6	-2.9933	0.1816	0.0741	0.2543	0.0010	0.0003
Vega	1	B2013.634	6	-3.0417	0.3026	0.1235	0.2548	0.0008	0.0002

Table 1. Calibration results. The final values used for Δ and E were found by averaging the results above: Δ = -2.9697˚, E = 0.2553 a.s./pixel.

Observational Methods

Each of the target double star systems was observed six times in the same manner that the calibration double was measured: each observation involved taking 2,000 images of the system, each image having an exposure time of 15 milliseconds. A Sloan R' filter was used to decrease the effects of atmospheric dispersion and isolate the speckle pattern in each image. Reduc was used to create an autocorrelogram from each FITS cube. This autocorellogram was analyzed in Reduc to find θ and ρ.

Results

Observations were made on two nights, the 19th and 20th of August, B2013.634 and B2013.637, respectively. Results are shown in Table 2. The values of θ and ρ reported for each double star are the averages of the six observations described in Observatonal Methods.

			Position Angle (˚)			Separation (arc. sec.)		
WDS #	Disc Code	Epoch	θ	Std Dev	Std Err	ρ	Std Dev	Std Err
16133 +1332	STF2021AB	2013.637	357.17	0.25	0.10	4.127	0.013	0.006
17146 +1423	STF2140AB	2013.637	102.89	0.52	0.21	4.976	0.086	0.035
17237 +3709	STF2161AB	2013.637	320.70	0.27	0.10	4.165	0.045	0.019
17564 +1820	STF2245AB	2013.637	290.55	0.63	0.26	2.636	0.032	0.013
18015 +2136	STF2264	2013.634	256.60	0.26	0.10	6.510	0.014	0.006
18078 +2606	STF2280AB	2013.634	183.08	0.08	0.03	14.383	0.056	0.023
19121 +4951	STF2486AB	2013.637	204.76	0.07	0.03	7.260	0.016	0.006
19457 +3605	STF2578AB	2013.637	124.38	0.05	0.02	15.023	0.033	0.013
19490 +4423	STF2588A,BC	2013.637	159.10	0.09	0.03	9.769	0.031	0.013
21200 +5259	STF2789AB	2013.637	113.90	0.04	0.02	7.057	0.035	0.014

Table 2. Results from observations of ten double star systems. Each system was observed six times, each observation yielding a fits cube of 2,000 images, each taken with an exposure time of 15 ms.

Figures 1-3 show our data points graphed along with the historical data kept by the United States Naval Observatory in the Washington Double Star Catalog (Mason & Hartkopf 2013). The Position Angles of the past observations were precessed using the procedure given by Greaney (2012). Of the ten systems observed, four have orbital solutions published in the Sixth Catalog of Orbits of Visual Binary Stars. Those systems are: STF2021AB, STF2140AB, STF2486AB, and STF2789AB. The past observations of two systems appear to curve; it is possible that these systems are gravitationally bound. Those systems are STF2161AB and STF2245AB.

In all graphs, the primary star is shown by the black 'plus', past observations are shown as blue stars, and our observation is shown as the magenta diamonds. North is at the bottom of the graph and west is the left side of the graph.

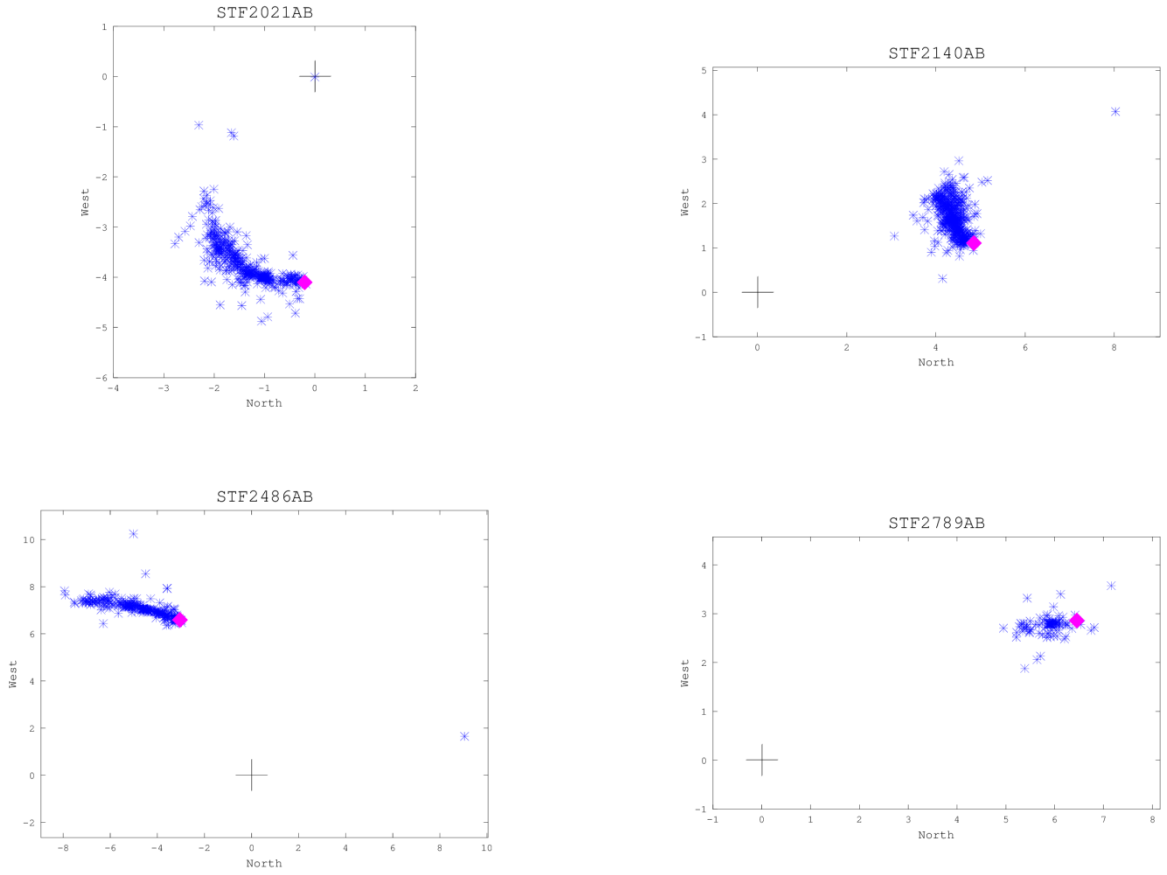

Figure 2. Observed double star systems which have orbits published in the Sixth Catalog of Orbital Elements. Past observations are shown by blue stars, while our observations are marked by the magenta diamonds.

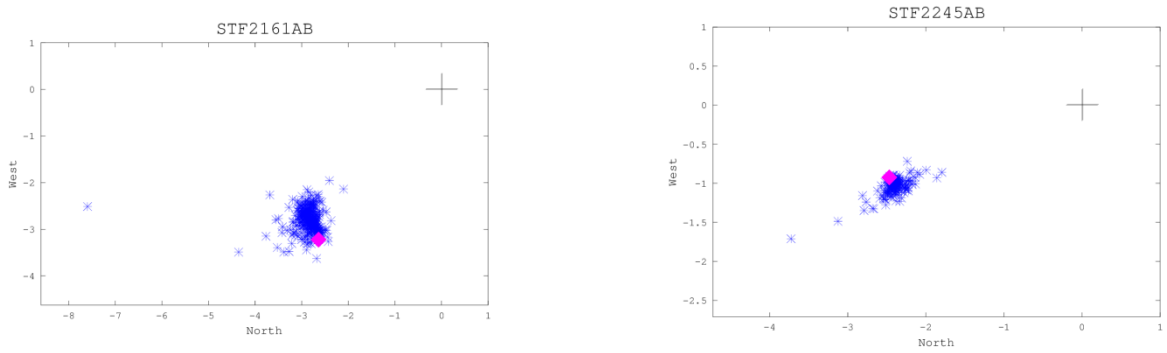

Figure 3. Two observed systems, STF 2161AB and STF2245AB, show interesting trends, perhaps indicating the systems are gravitationally bound. STF2161AB appears to be orbitting in a counter-clockwise direction, while STF2245 appears to be traveling clockwise.

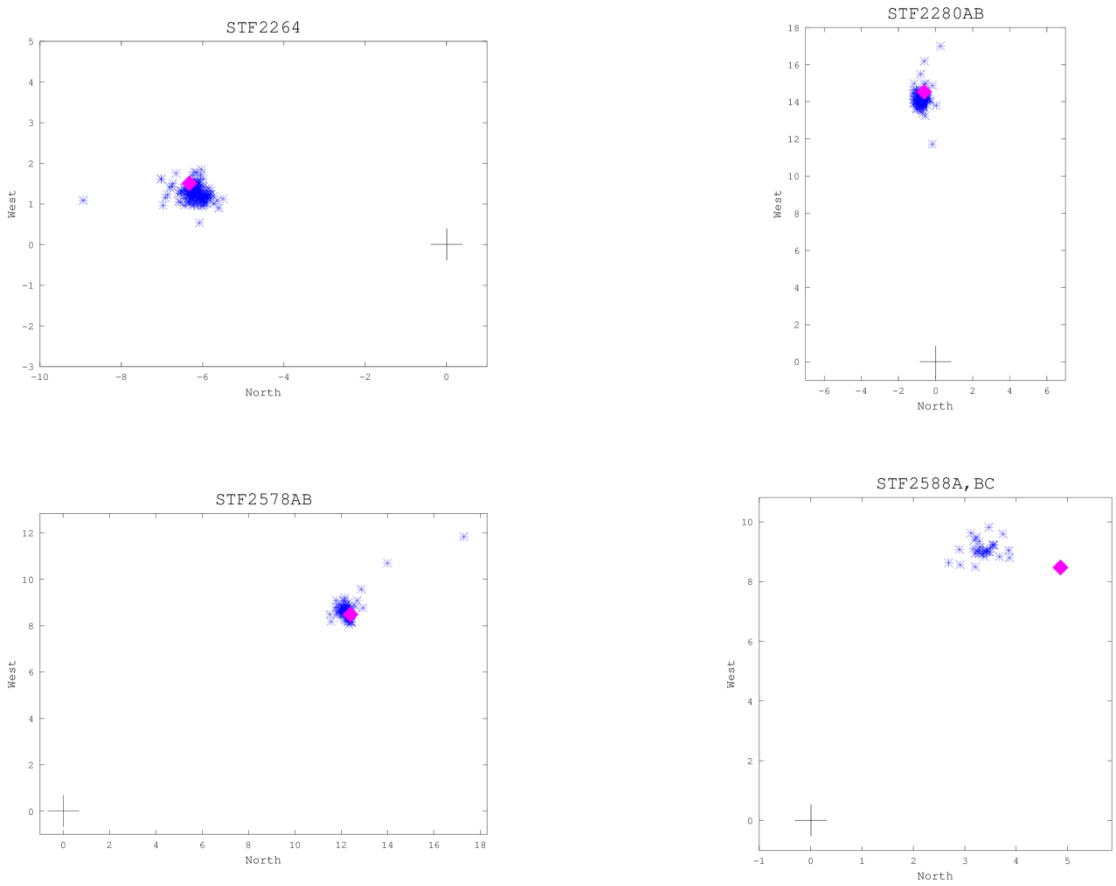

Figure 4. Graphs of the remaining four observed double stars. Past observations are shown with blue stars while our observations are marked by a magenta diamond.

Conclusion

Of the four systems with published orbits, STF2021AB is a grade 4 and has a period of 1354 years (Baize & Petit 1989), STF2140AB is a grade 4 and has a period of 3600 years (Baize 1978), STF2486AB is a grade 4 and has a period of 3100 years (Hale 1994), and STF2789AB is a grade 5 and has a period of 180 years (Kiselev et al. 2009). It seems unlikely that any of these orbits will soon be upgraded; in the case of the first three, the period is too long, and the last one was calculated very recently. The doubles STF2161AB and STF2245AB could possibly have orbits calculated after a few more observations are made.

Acknowledgments

The authors would like to thank Florent Losse for generously allowing us to use Reduc and for his help in understanding how to use the program. This research also made use of the past data kept by the United States Naval Observatory. Thanks are due to William Hartkopf and Brian Mason for their diligence and expedience in providing data from the Washington Double Star Catalog.

References

Baize, P. 1978. *Inf. Circ*., 76.

Baize, P. & Petit, M. 1989. *A&AS,* 77, 497.

Ding, Yuan-Yuan. 2015. Speckle imaging experiment with the 1.56 meter telescope at the Shanghai Astronomical Observatory. *The Journal of Double Star Observations*. In preparation.

Genet, R. M. 2013a. Portable speckle interferometry camera system. *Journal of Astronomical Instrumentation,* 2. 1340008-14.

Genet, R. M. 2013b. The Maui International Double Star Conference. *The Journal of Double Star Observations*, 9, 2, 158.

Genet, R. M., Hardersen, P., Buchheim, R., Mohanan, K., Church, R., Weise, E., Richards, J., Rowe, D., & Johnson, J. 2013c. Close double star speckle interferometry program. *Proceedings for the 32nd Annual Conference of the Society for Astronomical Sciences,* 61. http://www.socastrosci.org/images/SAS_2013_Proceedings.pdf

Greaney, M. 2012. Some useful formulae; precessing the position angle. In *Observing and Measuring Visual Double Stars,* 2. Ed. Argyle, R. W. New York: Springer, 355.

Hale, A. 1994. *AJ,* 107, 306.

Kiselev, A. A., Romanenko, J. G., & Kalinichenko, O. A. 2009. *Astr. Reports,* 53, 126. (SvAL 86, 148, 2009).

Mason, B. & Hartkopf, W. I. 2013. *The Washington Double Star Catalog*: Personal Correspondence.

Maurer, Andreas. 2012. The diffraction grating micrometer. In *Observing and Measuring Visual Double Stars,* 2. Ed. Argyle, R. W. New York: Springer, 184.