Consistency and Precision Measurements of Seven Double Stars

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Abstract

We observed seven faint double star pairs from the WDS catalog using data retrieved from Pan-STARRS1 Data Release 1 (DR1). The right ascension and declinations were measured by the program SAO Image DS9, or in the case of close pairs by fitting two Gaussians to the brightness profiles. After, we computed separation and position angles. The measurements of the seven targets were compared to the most recent results in the WDS catalog to verify consistency. Precision was calculated by using the standard deviation. Most of our results were very similar to the latest measurements on the WDS catalog.

Introduction

Double stars were selected from the Washington Double Star (WDS) catalog. Targets were selected on the basis of separation angle (ρ) and magnitude. Right ascension (RA), and declination (Dec) were also considered. Seven candidates were selected.

Both the Washington Double Star catalog and Simbad Astronomical Database were used to select the double stars and provide historical data on them (Armstrong and Tong, 2016). After finding an initial candidate list in the WDS catalog, Simbad was used as a preview to confirm that the target could be convincingly identified. In total, five bands were used collectively to observe the seven pairs—green (g), red (r), infrared (i), (z), and (y). Most of the observations used were g band images since they were found to be the least saturated.

Abbreviated entries from the WDS catalog, including historic measurements, magnitudes, and precise coordinates can be found in Table 1 (below).

Methods

The observations were obtained by the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS). Pan-STARRS is a system for wide-field astronomical imaging which was developed and operated by the Institute for Astronomy at the University of Hawaii (Chambers et al., 2016). The first part of Pan-STARRS to be completed is Pan-STARRS1 (PS1): it is the basis for both Data Releases 1 and 2 (DR1 and DR2). The PS1 survey imaged the sky using a 1.8 meter telescope and a 1.4 Gigapixel camera. This was done in five broadband filters (g, r, i, z, y). The Pan-STARRS1 telescope is situated at Haleakala Observatories which is near the summit of Haleakala in Hawaii. The PS1 survey includes observations of three quarters of the sky (3π). Targets that are north of -30 degrees (declination) are archived in the PS1 database (Flewelling, 2020).

Pan-STARRS Image Access supports two file types, stack and warp. The stack option combines all images of the same filter into a single image. The warp option includes single-epoch PS1 images that overlap the requested sky position (Flewelling, 2020). The warp option was solely used throughout this study since it allowed us to see the individual images and the different times they were observed. Images with saturation were rejected. Between 4-10 images were chosen for each of the seven targets, all images varying through the 5 bands (g, r, i, z, y).

WDS Identifier	Epoch		P.A		Sep		Magnitudes		Precise Coordinates	
	First	Last	First	Last	First	Last	Primary	Secondary	RA	Dec
BAL2467	1910	2015	83	95	11.2	8.7	12.52	13.2	180126.81	032416.4
ARA 455	1916	1999	96	96	11.8	11.6	13.0	13.2	180915.02	-182636.3
ARA 451	1916	2015	182	182	7.7	7.7	12.9	13.0	180745.39	-185203.0
ARA 731	1916	2011	216	223	5.3	6.2	13.0	13.1	180855.54	-190101.1
SLE 140	1982	2015	170	166	7.3	6.8	12.2	12.3	180742.75	560802.8
LOC 360AB	2015	2015	244	244	1.3	1.3	12.9	14.9	180251.79	762802.7
COU2391	1986	2015	103	97	1.2	2.2	12.8	14.8	180407.04	505148.0

Table 1: Abbreviated entries from the WDS catalog for the seven targets selected for this study.

Results

The right ascension and declinations were measured for the primary and secondary stars of each target in each of the individual Pan-STARRS images. For targets with larger separation angles (>2”), the right ascension and declination of each target was measured in each of the Pan-STARRS images using SAO DS9 (Joye and Mandel, 2003). The separation angle and position angle were then calculated. For the two targets with smaller separation angles, custom Python code was developed to fit two Gaussians to the point spread function of the stars (see Genet et. al). The separation angle and position angle were computed in pixels and then converted to arc seconds based on the plate scale reported by Pan-STARRS. The results are summarized in Table 2.

Table 2: Summary of Results.

Target/ Filter	Separation Angle	Position Angle	MJD
BAL2467	Measured using DS9		
G	8.85	93.8	55358.49

G	8.86	94.5	55358.51
G	8.71	94.6	56450.55
G	8.72	95.2	56456.37
Average	8.79	94.5	
WDS Measurements	8.7	95	
Standard Deviation	0.08	0.6	
Error of Mean	0.04	0.3	
• MJD for date reported by WDS Catalog were assumed to be June 1st of the reported year			
ARA 455	Measured using DS9		
G	11.47	97	55358.47
R	11.58	95.4	56532.29
G	11.47	97	56829.40
G	11.6	96.4	56841.43
Average	11.58	96.3	
WDS Measurements	11.8	96	
Standard Deviation	0.07	0.7	
Error of Mean	0.03	0.4	
ARA 451	Measured using DS9		
G	7.61	183.2	54999.50
Z	7.61	182.1	56198.23
G	7.71	182.1	56834.41
G	7.80	181	56834.42
Average	7.68	182.1	
WDS Measurements	7.7	182	
Standard Deviation	0.09	0.9	
Error of Mean	0.05	0.4	

ARA 731	Measured using DS9		
G	6.46	224.6	54999.50
G	6.42	226.8	55358.47
G	6.29	224.4	55710.56
G	6.36	223.7	55722.52
G	6.29	224.4	56475.38
Average	6.37	224.8	
WDS Measurements	6.2	223	
Standard Deviation	0.08	1.2	
Error of Mean	0.03	0.5	
SLE 140	Measured using DS9		
R	6.79	166.5	55376.32
Y	6.65	167.7	55403.40
Z	6.73	164.9	55438.23
R	6.57	166.8	55743.49
Z	6.89	166.7	55783.25
Z	6.81	165.8	55783.26
G	6.69	166.3	56481.38
G	6.79	166.5	56481.39
R	6.67	167	56481.40
Average	6.73	166.4	
WDS Measurements	6.8	166	
Standard Deviation	0.09	0.8	
Error of Mean	0.03	0.3	

LOC 360AB	Measured by fitting double Gaussian to PSF		
Z	0.77	393.3	55783.25
Z	1.05	242.7	55783.27
Y	1.34	252.1	56143.39
G	0.55	111.7	56473.38
Y	0.59	243.3	56902.23
Y	0.77	234.9	56902.23
Average	0.84	237.3	
WDS Measurements	1.3	244	
Standard Deviation	0.30	72.8	
Error of Mean	0.12	29.8	
COU2391	Measured by fitting double Gaussian to PSF		
G	2.02	97.3	55361.44
G	2.21	97	56091.42
G	2.21	96.9	56091.43
G	2.16	96.7	56145.26
G	2.12	96.4	56145.26
G	2.17	96.1	56145.27
G	2.21	96.9	56145.35
G	2.23	96.4	56447.51
G	2.24	97.7	56459.51
G	2.09	98.2	56459.52
Average	2.17	97	
WDS Measurements	2.2	97	
Standard Deviation	0.07	0.6	
Error of Mean	0.02	0.2	

Table 2: Summary of results. The separation angle is in arcseconds. The position angle is in degrees. The WDS measurements are the original measurements found in the WDS catalog. MJD represents the modified Julian date. The average is the mean of our results.

Discussion

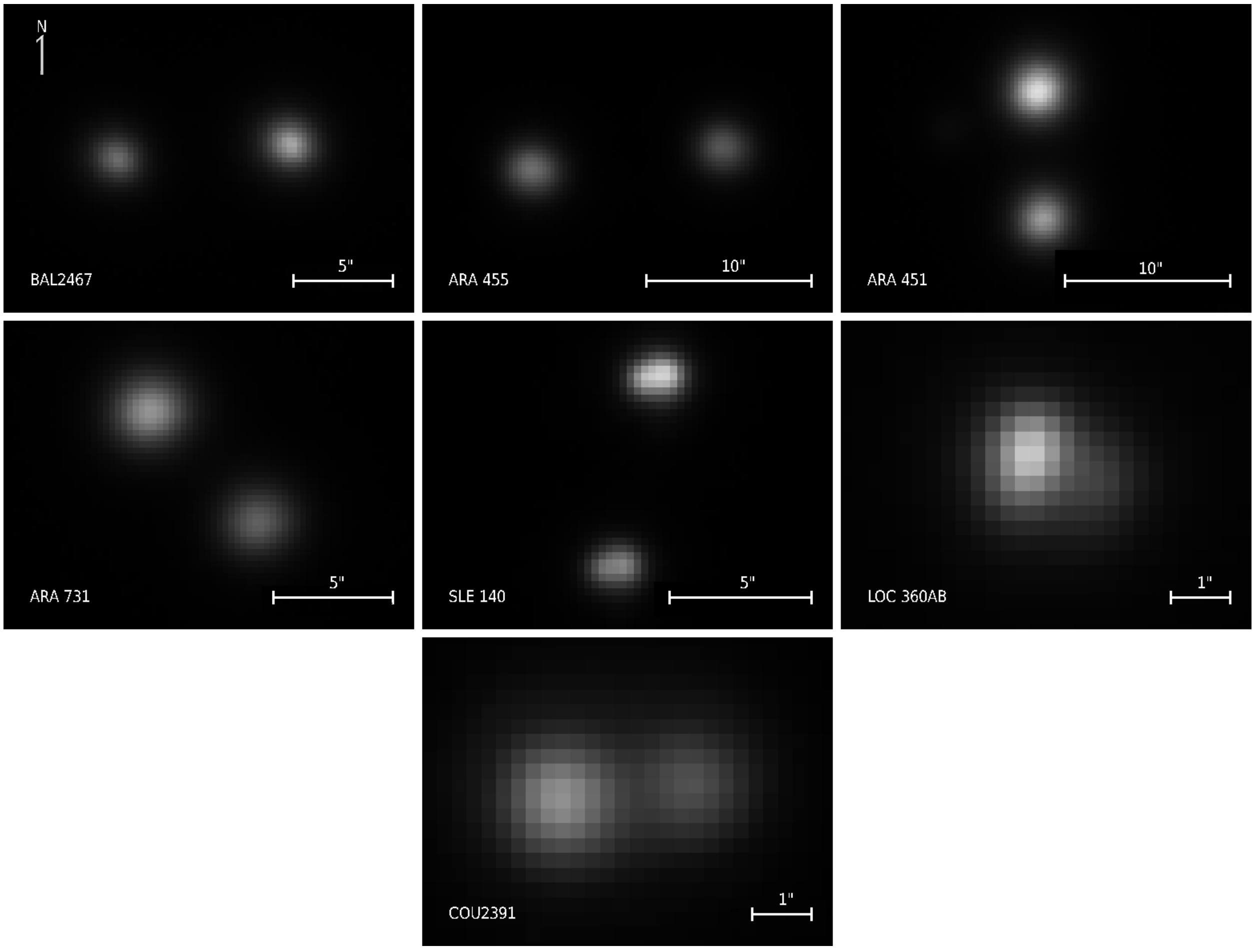

Figure 1: A sample image of each of the seven stars used in this study. All bands are in g, except for star LOC360 AB which is in the y band.

Due to difficulty in measurement of LOC 360AB, discussed below, we only considered 6 of the targets for this part of the discussion. Precision of individual measurements were measured by using the standard deviation of the separation and position angle. Nearly all position angle measurements had a standard deviation of less than 1°, the only exception being the standard deviation for position angle ARA 731 which was about 1.18°.

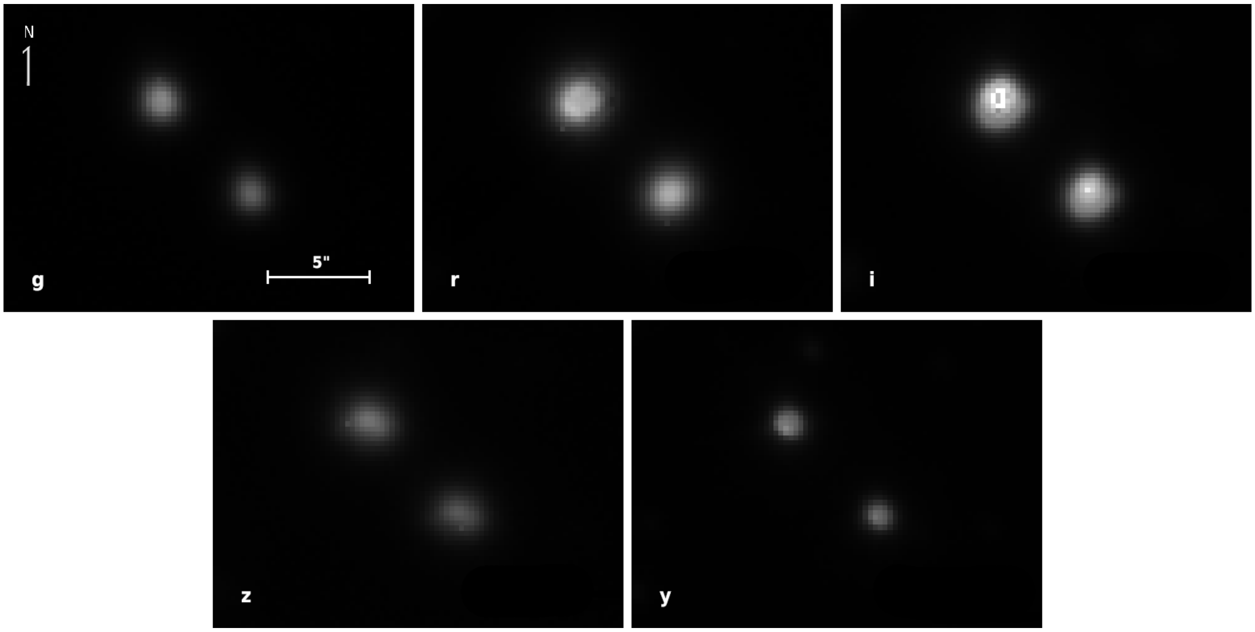

Figure 2: A side-by-side comparison of ARA 731 in each of the 5 bands: g, r, i, z, y

For target LOC 360AB our results were significantly different compared to the WDS measurements. Initially, a star 10’ away had been misidentified as one of the two components of the binary pair. After a closer look, we noticed that the double stars were actually paired differently, they were significantly closer than we thought they were and had mistaken a nearby star for the others’ counterpart. We then visually inspected the images. There were 2 images that clearly displayed an oval, a sign that they are a close pair. 2 other images had saturation within the pair. The Gaussian fitting routine gave inconsistent results and it was found that slight variations in the initial “guess” parameters gave results that varied wildly. It is likely that the separation angle is too small for reliable measurement with our data and methods. Any of these measurements should be viewed with a high degree of skepticism.

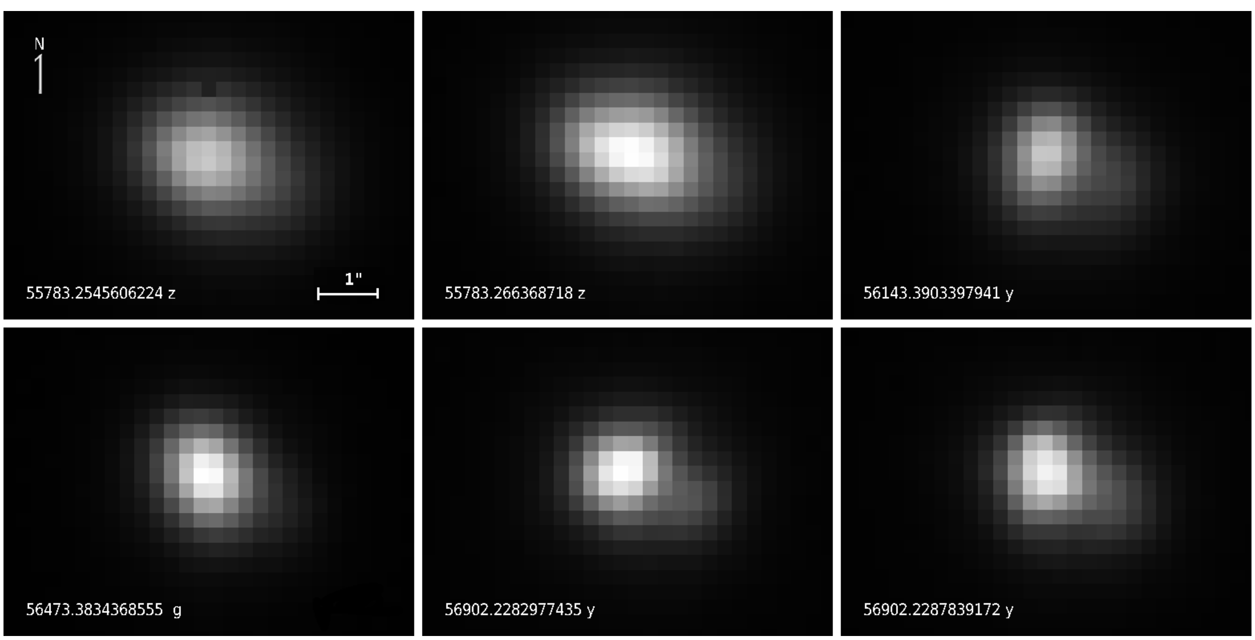

Figure 3: Sample image of LOC 360AB in bands g, y, and z during different MJDs

Conclusion

We measured the separation and position angles for seven faint double stars to find out how consistent and precise the results were when compared to the WDS catalog. Excluding LOC 360AB, typical precision was better than 0.1" for separation angle and 1° in position angle. Precision is estimated at 0.2" for separation angle and 2° for position angle. There is not enough data to confirm that any of the targets are gravitationally bound together. Future research for potential orbits can be done using data from this paper.

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