Observation and Investigation of 6 Common Proper Motion Doubles in the Washington Double Star Catalog

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Abstract

This paper presents the methodology used to identify suitable star pairs for observation using the Prompt telescopes. The selection criteria included the magnitude of the stars, the magnitude difference between the stars, their separation, physical relation, and visibility in the night sky. The paper also reports the results of measurements of position angle and separation for the selected star pairs using a 16-bit CCD camera. Afterglow was used to obtain measurements, and data for the relative proper motion (rPM) and mass calculations were obtained from Gaia DR3. We show that all systems examined in this study exhibit common proper motion. The paper demonstrates the suitability of using the Prompt telescopes for accurate measurement and observation of star pairs.

1. Introduction

Double stars provide important information about stars that may be binary systems on wide orbits, from which masses may eventually be determined from observed orbital characteristics. Even when a double star turns out not to be a binary system, if the two stars are at the same distance and have similar proper motions, they may still be physically related, having formed from the same gas cloud. In this case, continued observations of double stars might enable astronomers an opportunity to estimate the origin of the binary pair by extrapolating to a time when the two stars were closer together.

In this study, we analyzed observations of six double star systems taken with 0.4-m PROMPT telescopes in the Skynet Robotic Telescope Network, which were taken as part of a stellar astronomy course at the University of Saskatchewan. These telescopes were particularly useful in the course because observations of stars at any declination to be made remotely by students without having to travel to the opposite hemisphere.

To identify star pairs that were suitable for observation with the PROMPT telescopes, we established several search constraints. First, the secondary star in each pair had to have a magnitude of less than 18, as it was necessary for the stars to be bright enough to be visible through the 0.4m telescopes with less than 60-second exposures. Second, the primary star needed to have a magnitude greater than 9 to ensure an exposure of at least 3 seconds could be made without saturating the primary, as this typically ensures enough field stars are present in the PROMPT telescope's 10'x10' field for accurate WCS solution. Furthermore, we required the magnitude difference between the two stars (delta mag) to be less than 5 to avoid saturating the primary star while ensuring sufficient signal-to-noise from the secondary. We also required the previously recorded separation between the two stars to be between 5 and 20 arcseconds, as pairs that were too close together would be more difficult to resolve. Ideally, we preferred to select pairs that were physically related, with similar parallax and proper motions. Lastly, we selected only those pairs that were currently visible in the night sky and were not too close to the Sun, as targets located too close to the Sun would be obscured by scattered sunlight during daytime hours and would not be visible at night. In summary, these constraints helped us to identify suitable star pairs for accurate measurement and observation using the PROMPT telescopes.

Some of the stars selected through this process have been previously studied. We obtained the record of historic observations from the US Naval Observatory so all observations on record could be plotted together.

2. Equipment and Methods

Instruments Used:
The images used in this study were captured using a 16-bit CCD camera with an aperture of 0.4 meters. The telescopes used had a focal length that ranged from 4477.0 mm to 4576.0 mm, and an F-ratio between 11.0 and 11.3. Specifically, PROMPT2, PROMPT5, PROMPT-MO, and PROMPT-USASK telescopes of the Skynet Robotic Telescope Network. The telescopes were located at three different observatories: the Cerro Tololo Inter-American Observatory in South America, the Meckering Observatory in Australia, and the Sleaford Observatory in Canada. The telescopes had a field of view of 10.2 x 10.2 arcminutes, allowing for the capture of detailed images of the target systems.

Measurements:
Afterglow was used for the measurements in this study, first making sure that the images were not saturated, then the images were stacked, and the separations and position angles were calculated using Afterglow's plotter tool, as shown in Figure 1. The measurement data is shown in table 1. Data for the rPM and mass calculations were obtained from Gaia DR3 (T. Prusti, J.H.J. de Bruijne, et al., 2016).

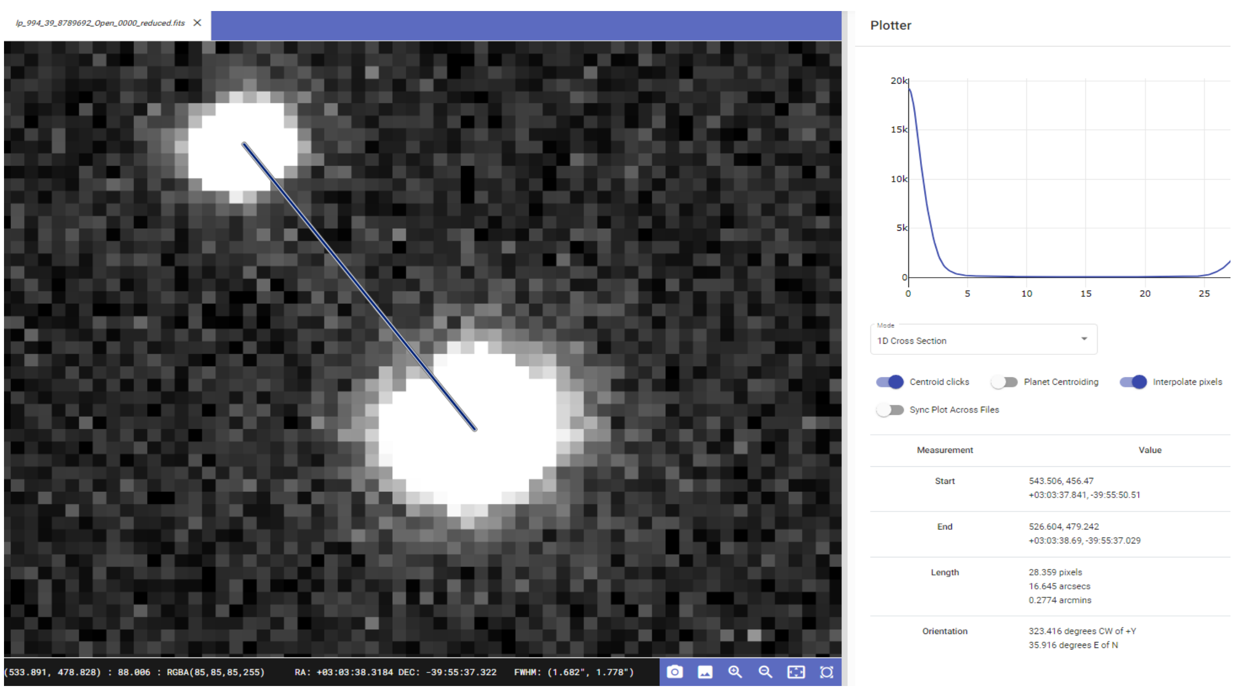

Figure 1: Example of Position angle and Separation measurements for TSN 48.

3. Analysis

Parallax and proper motion data for each system, including the proper motion ratio (rPM) calculated as the ratio of the PM difference vector magnitude to the magnitude of the longer of the component PM vectors. All of these systems except SKF 1010 have rPM lower than 0.2, indicating common proper motion**:**

The position angle and separation of each system was measured using Afterglow. The measurements are shown in Table 1. Data for the rPM and mass calculations were obtained from Gaia DR3 (T. Prusti, J.H.J. de Bruijne, et al., 2016).

Table 2 displays the target systems with their corresponding parallax and proper motion data from Gaia DR2. In order to assess the similarity of their movements across the celestial sphere, a proper motion ratio (rPM) was determined for each system using the following equations. The relative motion of the stars is computed by finding the magnitude of the difference vector between the primary and secondary proper motion vectors, which is demonstrated in Equation 1 (B. Bonifacio, 2020).

$$pm_{Mag} = \sqrt{(pm_{RA1} - pm_{RA2})^2 + (pm_{Dec1} - pm_{Dec2})^2}$$

Equation 1: Proper motion of stars

To evaluate the similarity of the component PMs, the proper motion difference vector's magnitude is divided by the longer proper motion vector's magnitude between the two stars. Therefore, a proper motion ratio (rPM) was calculated for each system.

$$rpm = \frac{pm_{Mag}}{\sqrt{pm_{RA1}{}^2 + pm_{Dec1}{}^2}}$$

Equation 2: Relative proper motion of stars

If the rPM for the system is less than 0.2, double star systems are deemed to have common proper motion (Harshaw, 2016). According to this standard, all of the systems listed in Table 1 exhibit common proper motion.

Table 1: Summary of Measurements.

System	Date	Number of Images	Position Angle (º)	Standard error on Position Angle	Separation (")	Standard Error on Separation
WDS 03036-3956 TSN 48	2023.0740	5	36.0	0.000	16.61	0.011
WDS 05354-7231 SKF 1010	2023.0849	1	171	0.007	14.7	2.877
WDS 04141+3543 ALI 60	2023.0750	5	120.716	0.036	14.041	0.008
WDS 00042+2701 SMA 1	2023.0767	5	161	0.079	13.4	0.02
WDS 05266+3524 STF 705	2023.0849	5	12	0.064	18.4	0.005

WDS 00042+2701 KPP 1604	2023.0 750	5	196	0.13	12.2	0.021

Table 2: Skeleton Table for Gaia Data.

System	Parallax of Primary (mas)	Parallax of Secondary (mas)	Proper Motion of Primary (mas/yr)	Proper Motion of Secondary (mas/yr)	rPM
TSN 48	8.807	8.758	212.365	212.111	0.001
SKF 1010	5.1714	5.177	15.833	15.025	0.952
ALI 60	3.88707	3.88465	-1.52038	-0.15208	0.043
SMA 1	1.8976	1.887	-2.657	-2.575	0.133
STF 705	2.8978	2.8335	-2.592	-2.56	0.120
KPP 1604	2.602	2.602	-1.084	-0.910	0.004

Parallax and proper motion data for each system, including the proper motion ratio (rPM) calculated as the ratio of the PM difference vector magnitude to the magnitude of the longer of the component PM vectors. All of these systems except SKF 1010 have rPM lower than 0.2, indicating common proper motion

Table 3: Estimates of mass, spatial separation, relative velocity, and escape velocity

System	Mass of Primary (solar masses)	Transverse separation in space (pc)	Upper Bound Escape velocity (m/s)	Relative 3D or 2D space velocity (m/s)
TSN 48	1.070	0.00914	1209	1402
STF 705	1.07	0.03078	742	2288
SMA 1	1.73	0.03424	59	1601
KPP 1604	0.6	0.02273	242	36144
SKF 1010	1.2	0.01378	1060	14934.540
ALI 60	1.14	0.01746	315	2357

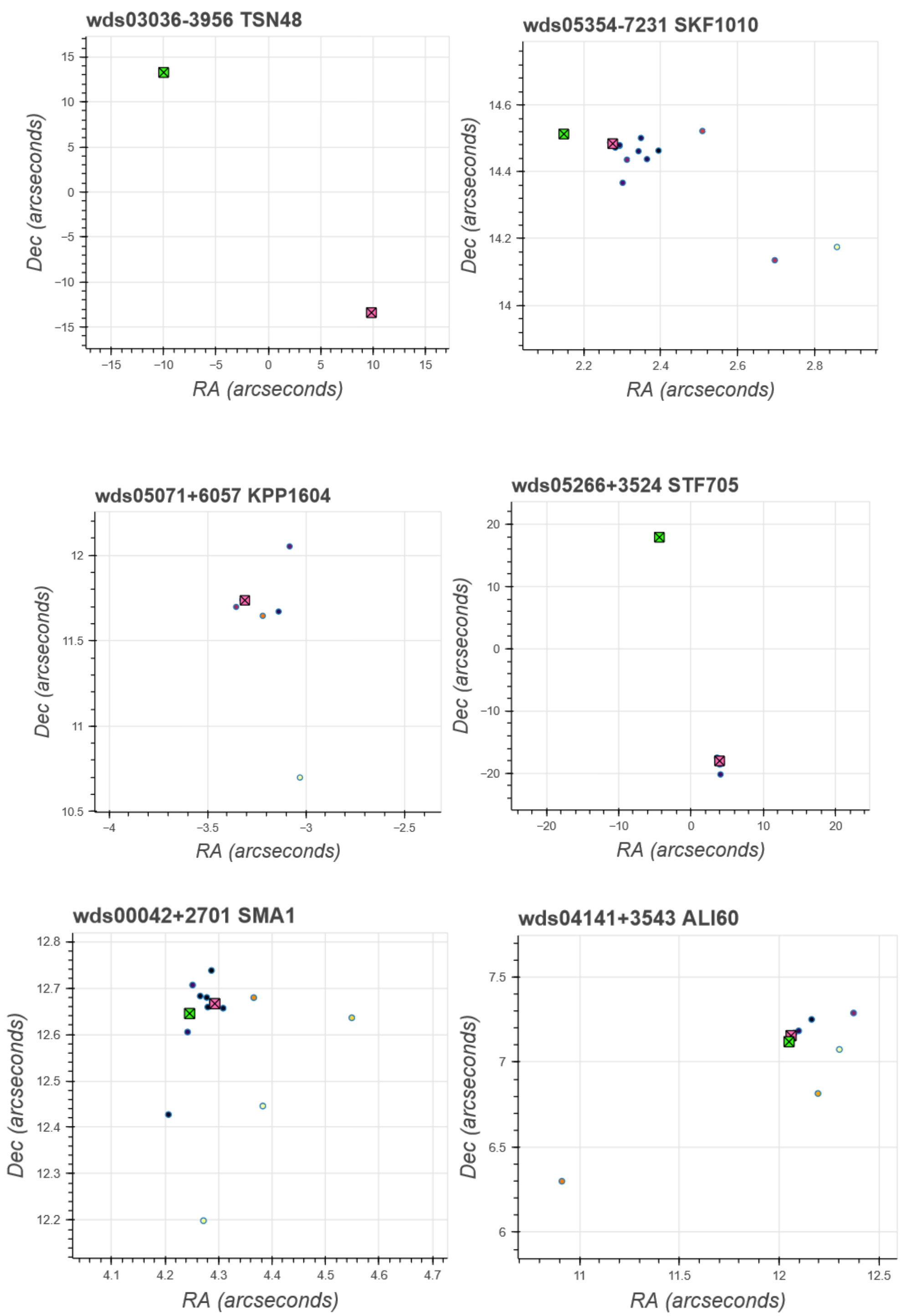

Figure 2: Previous measurements were obtained for each system from the US Naval Observatory. These measurements are shown in the plots below as circles, where the earlier the measurement, the lighter the circle. Alongside this historical data indicated with a green square is our data. The other red square is the measurement obtained from Gaia.

4. Conclusion

After implementing a set of search constraints, Stelledoppie was used to identify a set of potentially interesting, physically related double stars to observe with the Skynet PROMPT telescopes. Gaia distances and proper motions were then looked up to confirm that the targets were in fact located at the same distance and had similar proper motion, from which it was inferred that the stars are likely physically related. Observations were then analyzed so that position angle and separation of each system could be measured using Skynet's Afterglow tool, and proper motion data were obtained from Gaia DR3 for analysis. The results of the study indicate that all of the systems listed in Table 1 exhibit common proper motion, are at the same distance, and therefore are likely physically related and may have a common origin. Continued observations of these systems may enable astronomers in the future to estimate properties of their origins.

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