Astrometric Analysis of Double Star System WDS 10280+1950 STF 1435 in Leo

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Abstract: Astrometric measurements of position angle (***θ***) and separation (***ρ***) for double star WDS 10280+1950 (STF 1435) in Leo were made using the 0.4 m telescope of the Las Cumbres Observatory Global Telescope Network (LCOGT). A position angle of 202.64 (±0.04) degrees, and a separation of 8.47 (±0.01) arcseconds were measured. Our measurements, along with historical data, suggest a very slow orbiting system with a period > 10^4 yr. Based on parallax measurements from Gaia Early Data Release 3, a distance of ~193 ± 1 pc to the primary star is measured, with a projected physical separation of ~1635 ± 9 AU between the stars. GAIA data reveal that both stars in this system have closely matching parallax, proper motion, and radial velocity values. This strongly suggests that these stars are in a binary system.

Introduction

Binary and multiple star systems are the most common type of stars in the local Galaxy, where they may account for over 50% of the stellar population. The physics of binary stars, however, is uncertain with questions remaining about mass transfer, momentum redistribution, coevolution, and planet habitability (e.g., De Marco & Izzard, 2017; Izzard and Halabi, 2018). Astrometric studies of double stars will help identify true binary star populations and aid in understanding the properties of these ubiquitous systems.

This study reports astrometric measurements for double star system 10280+1950 (STF 1435) in the constellation Leo. This star system consists of two Sun-like stars that are too faint to be seen by the naked eye. These stars were discovered by Baltic-German astronomer Friedrich Georg Wilhelm von Struve in 1827. Since then, there have been 26 recorded astrometric measurements of this system (US Naval Observatory, personal communication). Before 1991, there were two extended periods of up to 30 yr. with no historical observations. However, after 1991 the system has been observed with a frequency of ≲ 7 yr. Both the primary and secondary stars in this system are of spectral type G0 (Halbwachs, 1986). The effective temperature of the primary is estimated at 6250 K and that of the secondary at 5500 K (Gaia, 2016; 2020). The magnitudes of the two stars are similar at 10.2 and 10.6 (Gaia, 2016; 2020). Analysis of the proper motion (μ) and separation (ρ) of this system suggests that the stars are gravitationally bound (Halbwachs, 1986). A parallax measurement of 5.1781 mas in the Gaia Early Data Release 3 catalog (Gaia EDR3, hereafter), indicates a distance of ~193 ± 1 pc (Gaia, 2016; 2020). Based on the observed angular separation of the two stars, and their distance from Earth, we estimate a physical distance of ~1635 ± 9 AU between the two stars.

Historical data measure a position angle in the range of 201.20 to 203.44 degrees, and a separation in the range of 8.18 to 10.23 arcseconds. These data are insufficient to define an orbit and there is no orbital plot available in the WDS ORB6 database. However, the similar physical properties and motion of these stars suggest a coevolving binary system. This study

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provides new astrometric measurements of the position angle and separation for this system using data collected with the 0.4-meter telescope of the Las Cumbres Observatory in Cerro Tololo, Chile (Brown et al., 2013).

Equipment and Procedures

Equipment

The system was observed on March 9, 2021 using the 0.4 m LCOGT robotic telescope with a SBIG STL-6303 CCD camera, utilizing a clear filter. The telescope is a Meade 16-inch RCS mounted on an equatorial mount. The SBIG camera has a field of view of 29.2 x 19.5 arcmin, and a plate scale of 0.571 arcsec per pixel.

Procedures

Ten images of the double-star system were collected with the LCOGT telescope to compensate for variations in atmospheric seeing and electronic noise. These variations would affect the apparent centroid positions of the two stars. Each exposure lasted two seconds and generated a bright, well-resolved image of the stars on the CCD detector. Prior to our analysis, the images went through standard pipeline processing by LCOGT for subtracting dark frames, flat frames, and bias frames.

The images were analyzed using AstroImageJ (version 3.4.0.25; Collins et al., 2017). The double star measurement tool in AstroImageJ was used to perform automatic centroid analysis and measurements of the position angle (θ) and separation (ρ) between the stars. This tool determines the position angle and separation distance from centroid to centroid of each star by looking at the plot profile of a line transecting both stars. The plate scale of the image was used to convert from pixels to arcseconds. The position angle is measured from North to East. The measurements were repeated on each of the ten images and averaged to account for atmospheric fluctuations and instrumentation noise.

Data and Results

New astrometric measurements and analysis of the double star system WDS 10280+1950 are presented below. Figure 1 shows the star system captured as a well-resolved pair by the 0.4 m LCOGT telescope in Spring 2021. The secondary star is located southwest of the primary at position angle 202.64 (±0.04) degrees.

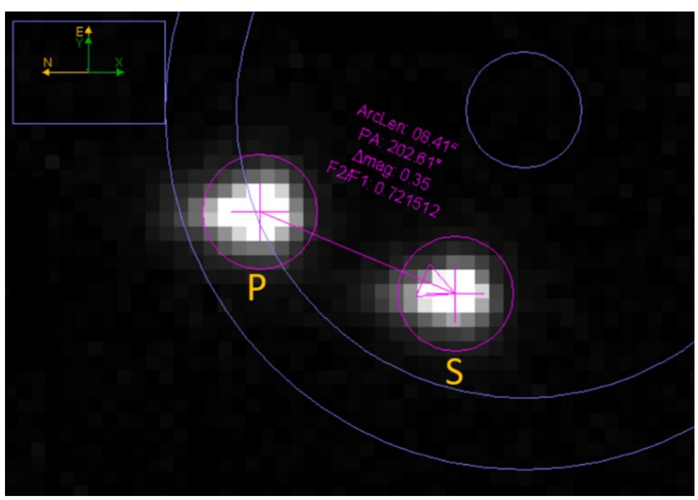

Figure 1. LCOGT image of WDS 10280+1950 displayed as measured with AstroImageJ. The primary star is labeled "P," and the secondary star "S." The magenta circles mark the centroids of the two star images, and the magenta text displays our astrometric measurements acquired.

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Table 1 lists measurements for position angle (**θ**) and separation (**ρ**) from ten LCOGT observations performed in this work.

Position Angle and Separation Measurements for WDS 10280+1950			
Obs. No.	Image Date and Time	Position angle (θ) (degrees)	Separation (ρ) (arcsec)
1	2021-03-09T03:22:54.993	202.69	8.47
2	2021-03-09T03:23:10.413	202.51	8.51
3	2021-03-09T03:23:25.832	202.66	8.42
4	2021-03-09T03:23:42.109	202.52	8.51
5	2021-03-09T03:23:57.585	202.48	8.41
6	2021-03-09T03:24:13.712	202.76	8.50
7	2021-03-09T03:24:29.148	202.63	8.38
8	2021-03-09T03:24:44.646	202.61	8.52
9	2021-03-09T03:24:59.930	202.93	8.46
10	2021-03-09T03:24:59.930	202.59	8.48
Mean		202.64	8.47
Standard Deviation		0.13	0.05
Standard Error of the Mean		0.04	0.01

*Table 1. Measurements for **θ** and **ρ** from ten LCOGT observations These measurements were made using photometric tools (Howell, 1989) in AstroImageJ.*

Figure 2 plots the historical measurements for WDS 10280+1950 in Cartesian coordinates, with corrections made for Earth's precession (Harshaw, 2020). These data were obtained from Dr. Brian Mason at the United States Naval Observatory.

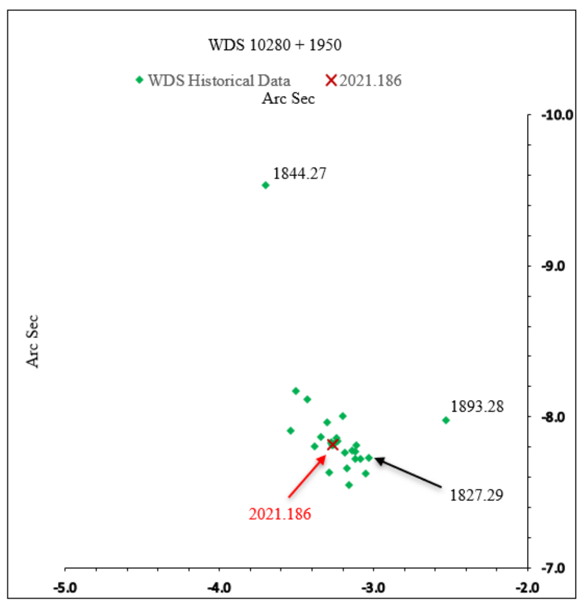

Figure 2. All historical data along with the current observation shown together. The current observation is shown as a red x. The primary star is at the origin (0,0). The observation dates for the two outliers are labeled, and the first measurement made by Struve in 1827 is indicated with a black arrow.

Discussion

This study reports on new astrometric measurements of the double star system WDS 10280+1950. It employs high-quality CCD images obtained with the 0.4 m robotic telescope of the LCOGT. Astrometric analysis was performed using custom tools for double stars built into AstroImageJ. Figure 1 shows the WDS 10280+1950 system as a well-resolved pair with a separation of 8.47 (±0.01) arcseconds. The secondary star appears slightly dimmer based on pixel count and intensity and is located southwest of the primary at position angle 202.64 (±0.04) degrees. These data are consistent with the physical properties of the stars reported in the literature (reviewed in the Introduction).

The measurements in this study are consistent with earlier historical measurements. Of the 27 historical measurements so far, there are only two that appear to be outliers. These are the measurements taken in the years 1844, and 1893 (Figure 2). The remaining 25 data points in Figure 2 are closely clustered, indicating that it is still too early to distinguish any geometrical pattern in the putative orbit of these stars.

Simple calculations using Kepler's third law suggest an orbital period of about 4 x 10^4 yr. These calculations assume a circular orbit, masses of 1 M_{Sun} for the primary and secondary (based on their G0 spectral type), and a separation of 1635 AU. Therefore, the data collected for about ~200 yr so far is insufficient to trace the geometry of the orbit. Both stars in this system have similar parallax, proper motion, and radial velocity values as measured in GAIA EDR3 (Table 2). This indicates the stars are in close physical proximity.

Both stars have similar masses, apparent magnitudes, and luminosities. They are thus likely to share similar evolutionary paths on the H-R diagram. Measurements in Gaia EDR3 indicate differences in the effective temperatures and BP-RP color indices of these stars (Table 2). These stars may therefore have different spectral types. Previous statistical analysis based on the proper motion and separation of these stars suggested that they are gravitationally bound (Halbwachs, 1986). Their estimated separation distance of ~1635 AU is also within the expected range of a bound system (Harshaw, 2018). Further studies and more observations will be needed to better constrain the orbital parameters of these stars and answer these open questions.

Component	Effective Temperature (K)	Photometric Color Index (BP-RP)	Absolute Stellar Parallax (Plx)	Total Proper Motion (PM)	Radial Velocity (km/s)
Primary	6250	0.701613	5.1781 (± 0.0293) (± 0.0293)	61.565 (± 0.029, ± 0.022)	23.88 (± 1.41)
Secondary	5500	0.732482	5.3801 (± 0.0148)	61.806 (± 0.014, ± 0.012)	24.36 (± 0.79)

Table 2. Gaia EDR3 measurement of parallax and proper motion for the star system WDS 10280 + 1950. The errors are listed in parentheses. The errors for proper motion are listed as error in RA followed by error in Dec.

Conclusion

The astrometric measurements of the double star system WDS 10280+1950 reported in this study are fully consistent with earlier historical measurements taken over the last 194 years. The closely clustered data suggest a system with a long period. Estimates using Kepler's third law suggest a period of several tens of thousands of years. Recent GAIA EDR3 data support the close physical association of the stars in this system. This study demonstrates how small robotic telescopes can be used to quickly and reliably perform astrometric measurements of faint double stars. Such studies will help better understand double star motion, interactions, and evolution.

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For the research project, we used the Washington Double Star Catalog maintained at the U.S. Naval Observatory, as well as the European Space Agency's (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).

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Additionally, we used the VizieR catalogue access tool, CDS, Strasbourg, France (DOI: 10.26093/cds/vizier). The original description of the VizieR service was published in 2000, A&AS 143, 23.

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