

# CCD Astrometric Measurements of WDS 12001+7039

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**Abstract:** The primary focus of this research was to acquire measurements for WDS 12001+7039 AB, AC, and AE system pairs through images acquired through the Las Cumbres Observatory telescope network (LCO), using a 0.4-meter Meade telescope. From the images we calculated the mean position angle and separation of the AB pair to be  $328.77^\circ \pm 0.03^\circ$  standard error and  $14.39'' \pm 0.01''$  standard error respectively, the AC pair to be  $158.77^\circ \pm 0.01^\circ$  standard error and  $30.61'' \pm 0.01''$  standard error respectively, and the AE pair to be  $317.13^\circ \pm 0.06^\circ$  standard error and  $25.21'' \pm 0.03''$  standard error .

## Introduction

Double Star WDS 12001+7039 is a quintuple star system, Figure 1, with multiple pairs having a record of historical measurements. This double star system was selected for research due to the AE pair only having a few historical observations; the first in 1885, and the last in 2003. As images were acquired for the entire system, pairs AB and AC were also measured in addition to AE. Measurements were not acquired for the D star (although there was historical data collected on the Cd measurement), because we found that the D star location was blown out in our measurements by the A star (by comparing locations in current measurements to the historic measurements).

The double star pair, 12001+7039 STH 2 AE has only 3 measurements in the last 133 years. A review of these historical measurements, provided by the United States Naval Observatory, show the position angle (theta) between the A and E components constantly at an average of  $317.5^\circ$ , however the separation (rho) between the two stars increased by 4 arc seconds from  $21.05''$  to  $24.81''$  during the same period.

## Equipment and Methods

The images for 12001+7039 were taken in Tenerife, Spain, through the Las Cumbres Observatory (LCO) system. Having access to 6 of the LCO telescopes around the world, this double star system was visible to three telescopes during the period requested: Tenerife, Spain, Maui, USA, and Texas, USA. The

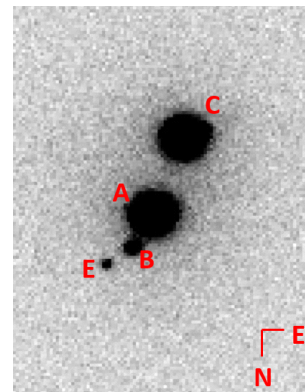


Figure 1. WDS 12001+7039

LCO scheduling system used the telescope in Spain due to weather and availability. A total of 20 images were taken through a Sloan Digital Sky Survey (SDSS) filter for the r band: Five with a three second exposure, five with a five second exposure, five with an eight second exposure, and five with a ten second exposure.

Once the images were acquired by LCO, each image was processed through the Our Solar Siblings Pipeline (OSS). The OSS Pipeline (Fitzgerald 2018) processes images in multiple phases that clean, label, and calibrate all images to prepare the photos for later measurements.

After the OSS pipeline processing, images were opened in the software suite Mira Pro for astrometric measuring using the Distance & Angle tool to accurately locate the stellar center of all stars for each measure-

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ment. Each separation and angle measure were recorded and organized in an Excel spreadsheet for calculation of the mean, standard deviation, and the deviation of the mean for the entire image set for each individual pair.

#### Results

The results for the Mean, Standard Deviation, and Standard Error of the Mean are reported for pairs AB, AC, and AE in Tables 1, 2, and 3 respectively.

#### Discussion

##### AB

There are 17 measurements in the historical record for the AB pair, plotted in Figure 2 using an Excel plotting tool by Richard Harshaw. The first measurements for these stars were taken in 1881 with a theta of 327.9° and rho of 13.82". The last measurement was in 2015 with the theta of 328.8° and rho of 14.56". The mean of the measurements taken in 2018 were a theta of 328.77° and rho of 14.39". During the last 137 years, theta has stayed the same while rho has decreased by

Table 1. Measurement mean and statistical errors for AB.

	Theta	Rho
Mean	328.77°	14.39"
Standard Deviation	0.15°	0.05"
Standard Error of Mean	0.033°	0.012"

Table 2. Measurement mean and statistical errors for AC.

	Theta	Rho
Mean	158.77°	30.61"
Standard Deviation	0.05°	0.04"
Standard Error of Mean	0.011°	0.008"

Table 3. Measurement mean and statistical errors for AE.

	Theta	Rho
Mean	317.13°	25.21"
Standard Deviation	0.26°	0.14"
Standard Error of Mean	0.057°	0.032"

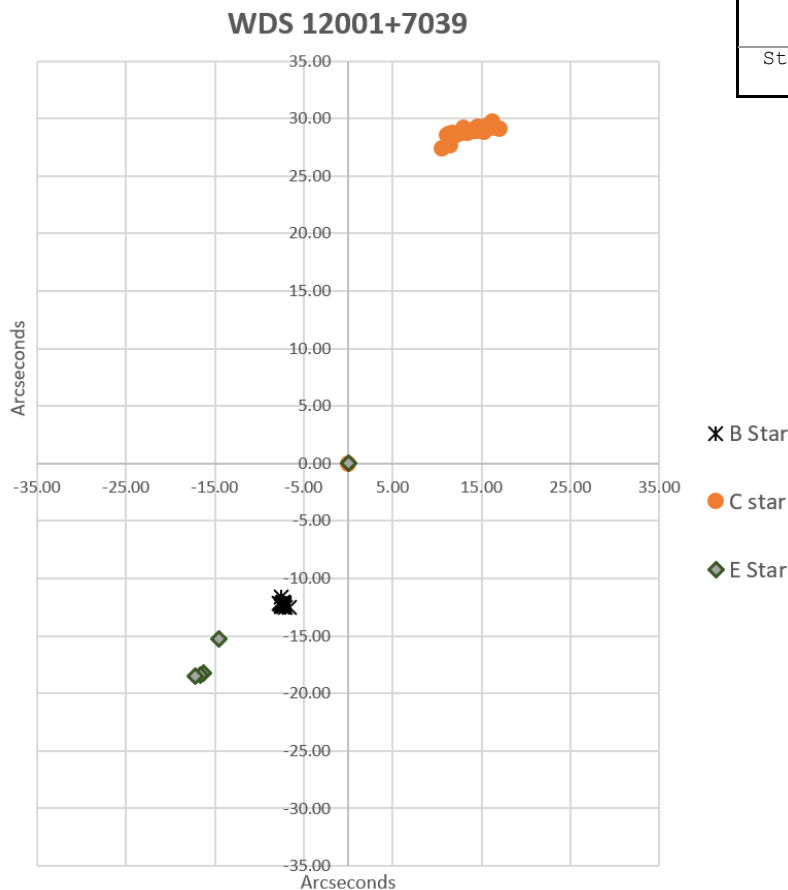


Figure 2. WDS 12001+7039 Measurement history from the WDS catalog.

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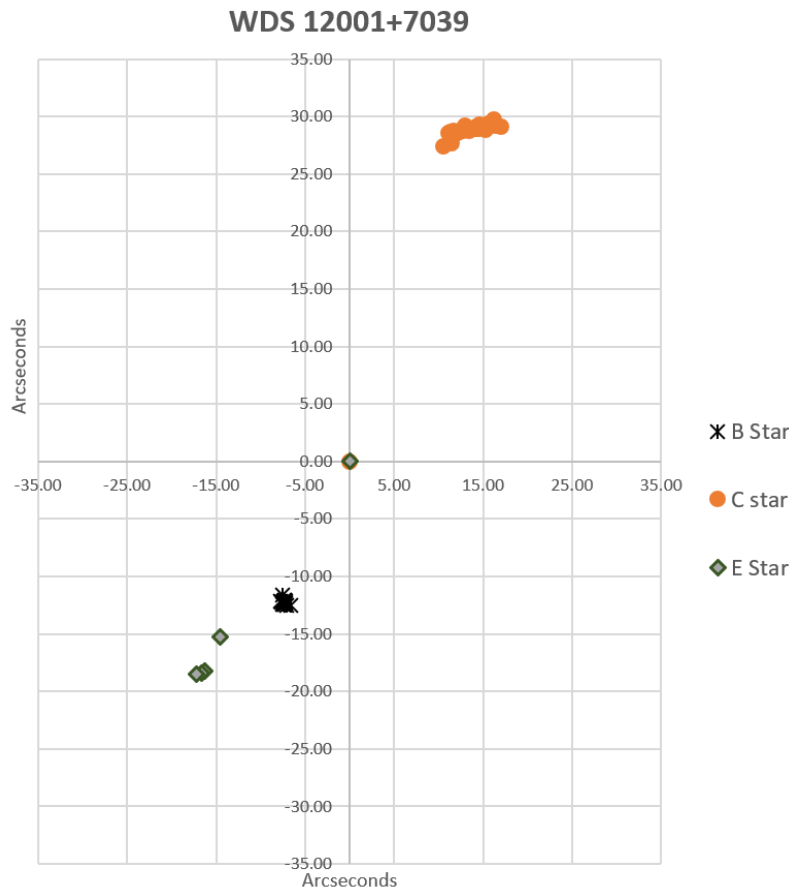
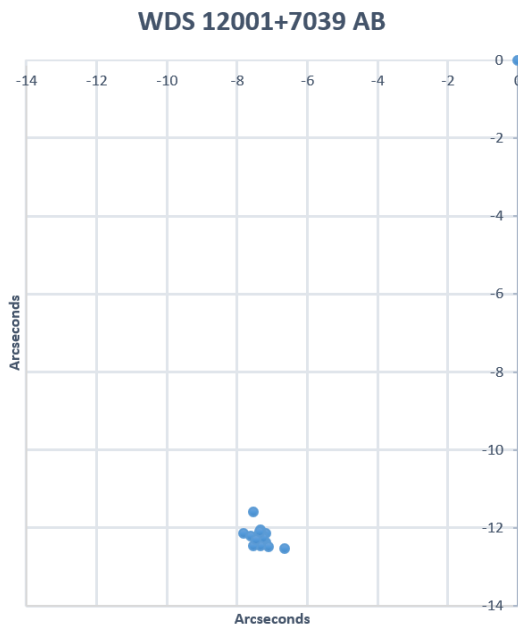


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0.16". Comparing all the historic data to the most current measurement, it's observed that there has been little to no movement in this star pair.

### AC

There are 39 historical measurements for the AC pair. The first measurements for these stars were taken in 1868. At the time the theta was  $149.6^\circ$  and the rho was 33.72". The last measurement was in 2015 with the theta  $158.4^\circ$  and the rho 30.74". The mean of our measurements in 2018 were a theta of  $158.77^\circ$  and rho of 30.61". By looking at the 39 historical measurements, Figure 3, there is an obvious linear movement, in which the current measurements fall into as well. Using the Excel *Add Trendline* function, Figure 4, there is a close linear fit for all measurements.

### AE

As stated above, the first measurements for this pair was taken in 1885 indicating a theta of  $316.5^\circ$  and the rho of 21.05". The last measurement was in 2003 with the theta of  $317.9^\circ$  and the rho of 24.81". The mean of the measurements taken in this project were a theta of  $317.13^\circ$  and rho of 25.21". There is an apparent curve in the visual data, however, this lies within a margin of error and therefore it is not currently possible to determine whether a linear or curved fit best represents the data.

## Conclusion

Through the images that were observed and measured, additional measurements were added to this rare quintuplet double star system including the AE pair which has few historical measurements. For the AB measurement the theta stayed at  $328.8^\circ$ , and the rho has decreased by 0.16", now being 14.4", and little to no movement has occurred. The AC theta has increased by  $0.4^\circ$  now being  $158.8^\circ$ , and the rho has decreased by 0.11", now being 30.6", adding to the linear observation. Lastly for the main measurement, AE, the theta had decreased by  $0.8^\circ$ , and the rho increased by 0.39", now being 25.2".

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