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FIRST SPECKLE INTERFEROMETRY MEASUREMENTS OF BINARY STARS AT THE OAN-TONANTZINTLA

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RESUMEN

Reportamos los resultados de las primeras medidas de interferometría de motas de nueve estrellas binarias. Las observaciones fueron hechas en febrero de 2006 con el telescopio de 1-m (OAN Tonantzintla, México) con el equipo DRAGON, el cual es un instrumento astronómico diseñado para llevar a cabo experimentos relacionados con imágenes astronómicas de alta resolución.

ABSTRACT

We report the results of the first speckle interferometry measurements of nine binary stars. The observations were performed in February, 2006 at the 1-m telescope (OAN Tonantzintla, México) with the DRAGON equipment which is an astronomical instrument designed to carry out experiments related to high-resolution astronomical imaging.

Key Words: **BINARIES: VISUAL — STARS: FUNDAMENTAL PARAMETERS — TECHNIQUES: INTERFEROMETRIC**

1. INTRODUCTION

The investigation of binary star motion is an important astronomical problem because it is the only direct way to measure the stellar mass. A great advance in the study of visual binary stars started with the publication of Labeyrie (1970) where the speckle interferometry technique was presented. This technique allows one to reach diffraction-limited resolution using special methods for the reduction of the short-exposure images. The main goal of this reduction is to remove the influence of the atmosphere from the observed data. The data reduction can be performed in two ways: either with the correlation methods or by Fourier analysis. The choice of the reduction method depends on the star separation, observational conditions and instrument's characteristics.

Applying the speckle interferometry technique, one can perform interesting and valuable scientific studies even with a relatively small telescope. For example, using the data obtained with 1-m class telescope one can get up to 0.1 arcseconds resolution which is enough to study many of visual binary and multiple star systems. For these purposes a speckle interferometer based on the DRAGON equipment (Voitsekhovich et al. 2005) has been developed. This instrument has been used for speckle observations of binary stars using the 1-m telescope at OAN-T in February 2006. In this paper we provide a brief description of the instrument and report the first results of the observations.

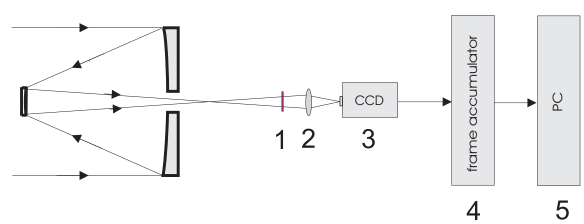

Fig. 1. The optical scheme of the speckle-interferometer. 1-The typical interference filter R. 2-Optical lens. 3-Detector (CCD camera). 4-Frame accumulator. 5-Computer.

2. BRIEF DESCRIPTION OF THE EQUIPMENT

The observations were performed with the DRAGON instrument which is described in detail in Voitsekhovich et al. (2005). In order to obtain data suitable for speckle interferometry, some minor modifications of this instrument were made, allowing one to include an additional objective and an inter-

TABLE 1

OBSERVATIONS OF STF1311 AB

Date	P.A.	Sep.	RefCode
1831.31	200.5	7.2	(Aitken 1932)
1991.25	199.2	7.625	(Perryman 1997)
1991.75	198.4	7.595	(Hoeg et al. 2000)
2005.296	198.9	7.72	(Daley 2006)

ference filter. The optical scheme of the instrument part related to the speckle interferometry observations is shown in Figure 1.

The parameters of the optical scheme are chosen in such a way as to provide a resolution on the CCD plane equal to 0.045 arcseconds/pixel (the total field of view at the CCD plane is equal to 23. arcseconds). The CCD size is equal to 4.8×6.4 mm (584×582 square pixels). In order to provide coherence in the light the standard interference R-filter is used.

The instrument records and stores the digitized data at a speed of 25 frames/sec. In order to provide a faster readout the frame accumulator with a capacity of up to 1500 of frames is used. After each observation the data accumulated during the experiment are transferred to hard disk.

3. OBSERVATIONS AND DATA REDUCTION

The observations were carried out on February 16, 2006 (Besselian year = 2006.128) with the 1-m telescope at the OAN Tonantzintla, México. Nine stars with separations from 0.21 to 1.9 arcseconds were chosen. The seeing during the observations was around 2 arcseconds. One or two sets of 1000 short-exposure images were accumulated for each binary star observed.

The calibration of the speckle data was performed observing wide binaries with very long orbital periods. STF1311 AB (ADS 7187, 09074+2259) is one of the well-known visual double stars with a very slow motion. Taking into account the above considerations we consider this star system as a good candidate for the calibration of our interferometer. The first reported observations in ADS Catalogue (Aitken 1932) were done in 1831 while the last ones were performed in 2005.296 (Daley 2006). In Table 1 the measurements of the position angle and the separation of these two stars are presented.

The calibration results show that the camera orientation error is less than 2 degrees and the scale error is less than 1.5%.

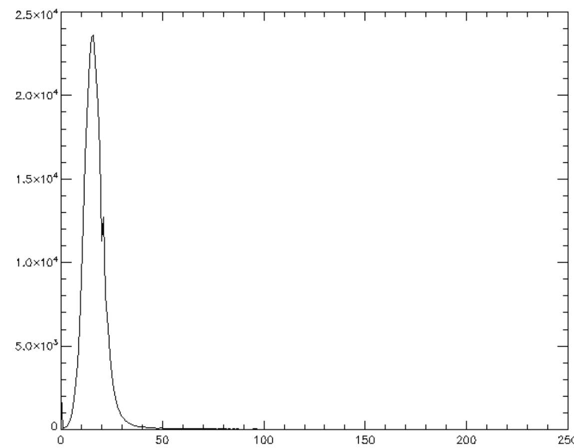

Fig. 2. The intensity histogram of a speckle image.

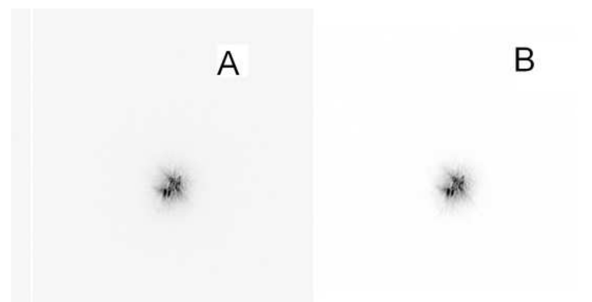

Fig. 3. Left image (A) is a speckle image before data processing (raw data). Right image (B) is the speckle image after data preprocessing.

We note that the accuracy obtained for the 1-m telescope depends on the separation between the stars and on the effective focal length of the system.

The speckle data reduction is made in three steps.

In the first step, we remove the additive noise from each speckle image. The value of the noise is chosen as an argument of the intensity histogram at its maximum (Figure 2).An example of the additive noise filtering is shown in Figure 3.

The second step is the calculation of the square modulus of the complex visibility (power spectra) averaged over all the images, which is performed according to the standard Labeyrie procedure (Labeyrie 1970). The Fourier transform of the power spectra (PS) gives the autocorrelation function (ACF). The atmospheric distortions are removed from this spectrum using the Wiener Filtering. Examples of the PS and of the ACF are shown in Figure 4.

TABLE 2

SPECKLE MEASUREMENTS ON THE 1-M TELESCOPE

WDS	ADS	P.A.	Sep.
06149+2230	4841	256.2	1.65
07128+2713	5871	309.2	1.01
07205+0024	5996	171.4	0.68
09020+0240	7152	268.4	1.1
09184+3522	7286	48.1	1.9
10260+0256	7769	297.0	0.21
10279+3642	7780	218.8	0.395
11125−1830	8086	315.7	0.258
11137+2008	8094	317.1	0.55

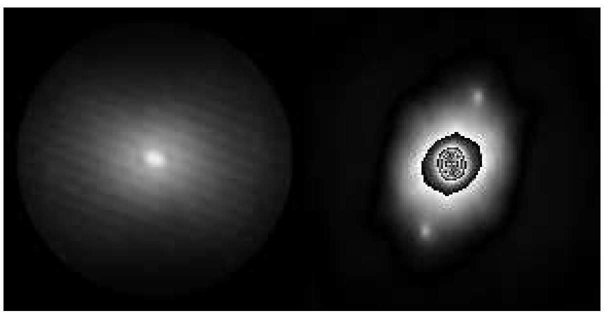

Fig. 4. PS (left) and ACF (right) of ADS4841.

In the final step, we measure the distance between the stars and the position angle.

4. RESULTS

The measurement results are presented in Table 2. The first column lists the Washington Double Star Catalog number (Worley & Douglass 1996) or the epoch-2000 coordinates. The second column is the number of the star from Aitken's double star catalogue (Aitken 1932). Columns 3 and 4 show the measured angular separation ρ in arcseconds and the position angle θ in degrees. The epoch of the observation was 2006.128 in fractional Besselian years. We do not present here cases where the binary was not resolved. This might indicate a very close companion or a very large magnitude difference (more than 3 magnitudes).

ADS 4841 (06149+2230, BU 1008, HD 42995, HIP 29655) is a binary star which shows slow motion. The orbital elements of this star (Baize 1980) are: P=473.7 yr, T=1819.7; e=0.54; $a = 1''.08$; $\Omega = 84^\circ.5$; $i = 142^\circ.7$; $\omega = 26^\circ.2$. The primary component is very bright, M1=3.52. The magnitude difference in V band M2-M1, is equal to 2.65. The PS and ACF of this binary are shown in Figure 4. The second component is clearly seen despite the big difference in magnitudes.

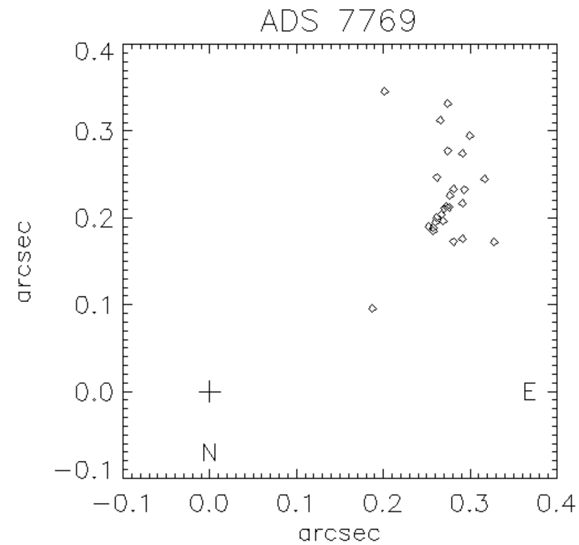

Fig. 5. Observations of ADS 7769.

ADS 5871 (07128+2713, STF1037AB, HD 55130, HIP 34860). The orbit of this object is known. The orbital elements are as follows (Soderhjelm 1999) P=119.0 yr, T=1920.7, e=0.93, $a = 0''.8$, $\Omega = 19^\circ$, $i = 141^\circ.0$, $\omega = 244^\circ$. The ephemerides for the date of our observation ($\rho = 1''.08$, $\theta = 311^\circ.13$) differ from our measurement by $\Delta = 0''.0783429$.

ADS 5996 (07205+0024, STF1074AB, HD 57275, HIP 35576). The orbit of this object is unknown due to the slow motion of the components. The first measurements for this object were made in 1831. Up to now only 28 measurements in total are available (18 of them were made in 1980-1997).

ADS 7769 (10260+0256, A 2570, HD 90361, HIP 51061) The first measurements were done in 1913. The results of all the measurements are shown in Figure 5.

ADS 8094 (HD 97561, HIP 54844) The object is a binary with a separation of $0''.55$. The difference in magnitudes is very small M1= 6.93 M2= 6.95. The first reported observation was done in 1829. In 1936 Arend (1936) concluded that there is no question about the physical connection of the two components and gave the following formulae for ephemerides calculation, assuming a very long period:

$$\rho \cos(\theta - 208^\circ.4) = +0''.177 \quad (1)$$

$$\rho \sin(\theta - 208^\circ.4) = -0.00952\,(t - 1941.87) \quad (2)$$

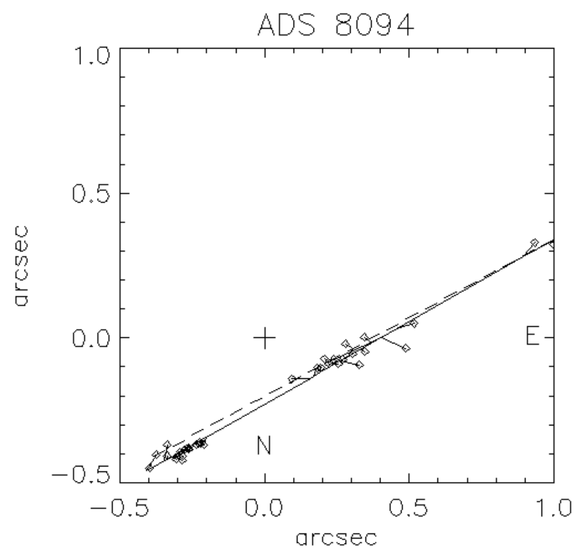

Fig. 6. Lineal approximation of observations of ADS 8094. The solid line expresses the relative motion calculated by formulae (3) and (4). The dashed line is calculated by formulae (1) and (2).

The orbital elements have been calculated and published by Hopmann (1970) as follows: P=4050. yr, T=1964.8; e=0.83; $a = 2''.406$; $\Omega = +39^\circ$.; $i = 116^\circ.3$; $\omega = 30^\circ.4$. However, Rutkowski & Waniak (2005) noticed that the ephemerides calculated by the orbital elements are very different from the observed ones. Also, they concluded that the previously observed relative trajectory contradicts the presumed double nature of this object. However, because this conclusion is based on a short period of observations (Hartkopf, Mason, & Wycoff 2004), it needs stronger justification. For this reason we decided to examine all the observed data since 1829.

First we calculated a linear approximation to the data. Assuming the correctness of this approximation, the ephemerides can be calculated by the following formulae:

$$\rho \cos(\theta - 209^\circ.6) = +0''.198 \quad (3)$$
$$\rho \sin(\theta - 209^\circ.6) = -0''.00917\,(t - 1942.69) \quad (4)$$

The result of this calculation is shown in Figure 6. As one can see the linear approximation fits quite well the observed data. However, the question about the orbit is still open.

5. CONCLUSION

The observations of binary stars have been performed with the 1-m telescope at the Observatorio Astronómico Nacional at Tonantzintla (OAN-T), México using the modified DRAGON instrument. The data reduction with speckle interferometric methods has shown that binary stars with separations of more than $0''.1$ can be measured. The measurement errors are as follows: in position angle $< 2^\circ$ and in separation < 0.06 arcseconds. The results have also shown that we could observe binaries with a secondary as faint as 9th magnitude. However, we expect that with an improved image intensifier and cooling the photocathode the limiting magnitude will be near 11. We expect to resolve binaries with magnitude differences of up to 3.

Most of the stars observed are of 7th-8th magnitude with separations 0.2-2 arcseconds and the maximum difference in magnitudes is 2.65.

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