Speckle Observations of Close Double Stars with a 1.2 m Cassegrain Telescope in 2021

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Abstract

A Cassegrain reflector with aperture 1.2 m was used for investigating close double stars at the northern sky. In particular, the binary systems STF 205 (γ And), STF 228, STF 3050, STT 515 (φ And) (all in Andromeda), as well as STFA 43/MCA 55 (Albireo, ß Cygni) were studied in some detail for checking orbital motion, and for comparing with existing ephemeris calculations. In each case, series of several ten thousand frames were analyzed with speckle interferometry. Calibration of the image scale was obtained by referring to data from Gaia and/or from the Washington double star catalogs.

1. Introduction

Despite the unprecedented accuracy of position data from Gaia, earthbound observations of double stars are still worthwhile for several reasons. One problem of Gaia is that close companions of stars brighter than about 4 mag are mostly not resolved, which is partly caused by saturation of the detectors. Also, the life time of Gaia will be limited, at least with respect to typical orbital periods of visual double stars. The binaries chosen for this study are interesting for various reasons.

MCA 55Ac forms a close binary with Albireo Aa, while component B is at a distance of roughly 35". Interest has recently increased as to the question, whether AB is a physical binary. This has become doubtful after Gaia Data Release DR2 was published in 2018, according to which the distance in between AB in the line of sight would be as large as 62 ly [1]. While this was reduced to about 35 ly in eDR3, with non-overlapping error margins, the binary nature of the pair would be excluded. One of the problems with this system is the brightness of Aa, as was mentioned above. We have discussed Albireo already in an earlier paper, but no definite conclusion as to the status of AB could be drawn from recent revisions of the orbit of Aa,Ac [2].

STF 205 is famous and colorful γ And, with component A of spectral class K3, and B at distance of 9.6", which itself is the close double STT 38 BC, with spectral classes B8+A0. This pair has not been resolved in recent years, and the last entry in the WDS gives a separation of 0.219" in 2010. It has intermittently decreased, and is now widening [3]. The assumed orbital period is 63.7 years.

STF 3050 AB in And has been thoroughly investigated in the past. Its period has recently been calculated by Izmailov to 323 years [4], and the current separation is about 2.5". While the pair is resolved by Gaia, the ephemeris does not quite fit the observations, both from Gaia, and ours.

The orbit of STF 228, also in Andromeda, is well documented, but observing with small telescopes will become a challenge in the near future, as the separation, now at about 0.5", is closing in.

The period of the binary φ And (STT 515 AB) is currently assumed to 554 years, but the orbit is only half ways covered with observations, of which less than about one quarter are speckle measurements or results from comparable methods.

2. Instrumentation

We used the T1T, the Trebur 1.2 m Cassegrain telescope with a focal length of 9.51 m. It is located in Trebur, Germany, and is operated by the "Astronomie Stiftung Trebur". On three nights in July, September, and November 2021, several series with up to almost 73000 frames of the above mentioned objects were recorded with a QHY 174M camera equipped with a fast and sensitive CMOS sensor. Exposure times were set between 2 to 10 ms to get rates of up to 480 frames per sec. Mostly a Barlow lens was used to extend the focal length to about 15 m. For Albireo, a photometric Johnson-blue-filter was inserted in order to compensate for the large color contrast of the components. In all other recordings, a Cousins-I-filter was used, as seeing effects are reduced at longer wavelengths.

For determining the east-west alignment of the field of view, star trails were recorded while the stars were allowed to drift through the FoV. Offset angles ranged from 1 to 2 degrees.

3. Image Processing and Calibration

Before analyzing, frames were mostly re-sampled 2x2 or 4x4, which resulted in smoothening of the intensity profiles, so as to better define the peak centroid. Speckle images were analyzed with the program “Reduc” by Florent Losse [5]. A few series were also searched for “lucky images”, which were aligned and stacked with the program “RegiStax” [6]. The nominal image scale without Barlow lens was calculated from the focal length of the telescope of about 9500 mm and from the pixel size of the camera of 5.86 µm, which results in 0.130 arcsec/pixel. This was refined to 0.1272 arcsec/pixel by measuring the separation of the pair Albireo AB, of which rather precise position data are provided by Gaia [1] (see below). The image scale with Barlow lens was independently determined by measuring the pair STF 205 AB (γ And) without and with Barlow, which led to a calibration factor of 0.08051 arcsec/pixel for the configuration with Barlow lens. These calibration factors were further checked for plausibility by additional measurements of STF 3050 AB and STT 228, as was already mentioned above.

4. Results

STFA 43 AB/MCA 55 Aa,Ac (β Cyg, Albireo)

This system was imaged in several series – in total more than 264000 frames – on July 28th/29th, 2021, without Barlow, so as to include the distant companion B in the field of view. A Johnson-blue-filter substantially enhanced the visibility of the dim companion Ac against much brighter Aa (see table 1). Representative results from lucky imaging and speckle correlation are shown in figures 1 and 2, respectively.

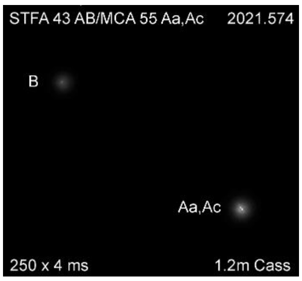


Fig. 1: Lucky imaging of the Albireo system with a 1.2 m Cassegrain telescope and a QHY 174M camera without Barlow lens at the date indicated at upper right. 250 frames with 4 ms exposure were selected from a series with several thousands and separately registered on A and on B, and superposed. North is off to the left from the vertical by 0.4 degrees

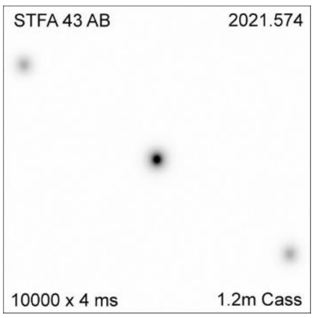


Fig. 2: Speckle autocorrelation of 10000 frames à 4 ms of Albireo AB recorded as in fig. 1. Image is inverted. The separation and orientation of the spots corresponds to rho and P.A. of AB

Measuring the distance (Aa,Ac)-B was intended for calibration of the image scale, in particular as Gaia DR2 and eDR3 have delivered highly accurate positions of A and B for the epochs 2015.5 and 2016.0, from which separations rho are calculated to 34.590 and 34.595 arcsec, respectively. However, other recent data from the literature exhibit significant scatter. In particular, the last entry in the WDS from 2020 (see table 1) appears to deviate from the general trend.

Table 1: Reference data for Albireo from the USNO catalog "WDSprecise" as of Feb. 2022 [3]:

name	RA & Dec	mag	Spectrum	P.A./deg	rho/arcsec	date
STFA 43 AB	19307+2758	3.19 4.68	K3II+B9.5	53.60	34.89 (?)	2020
MCA 55 Aa,Ac		3.37 5.16	K3III+B0V	46.00	0.335	2021

While literature data seem to indicate a slow increase of rho(AB) in the long term, occasional outliers as low as about 33 arcsec and as high as almost 36 arcsec have tentatively been attributed to the orbital motion of AaAc [7]. However, a definite correlation is not clear, and the exact period is still in question [2]. Proposed values range from below 100 years to greater than 200 years (see below). In any case, this would not explain an increase of rho by 0.3 arcsec within the recent five years. It may be noted that AaAc is not resolved by Gaia, and the measured position of A is dominated by Aa. Extrapolation of the positions from Gaia to the epoch of our measurement (~ 5.7 years) leads to a separation of AB of 34.650". We take this as reference for calculating the image scale.

The main intention of investigating Albireo was to measure the close double MCA 55 Aa,Ac. Three series of recordings were processed after enhancing the contrast, and with re-sampling, as explained above. Figure 3 shows a representative image of speckle autocorrelation of 7326 frames.

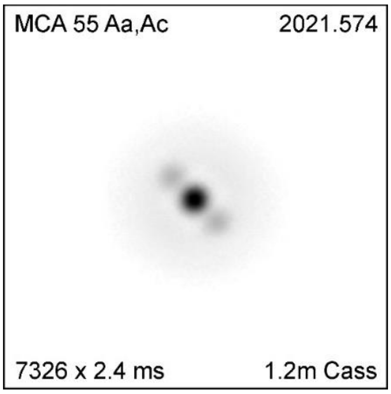


Fig. 3: Speckle autocorrelation of MCA 55 Aa,Ac, recorded at the date given at upper right. Result from 7326 frames of a series with exposure time 2.4 ms. Image scale increased

Mean values for the position angle and separation were obtained as 46.0º ± 2.0º and 0.335" ± 0.015", respectively. This position is close to our measurements in 2019 and 2020, which were presented in our earlier paper [2], and all three are close to recently revised orbit calculations by M. Scardia [8], R. Drimmel et al. [9], and B. Mason [10], which are plotted in fig. 4. However, the angular coverage with observations (speckle data [11]) is still limited, so future revisions will be pending.

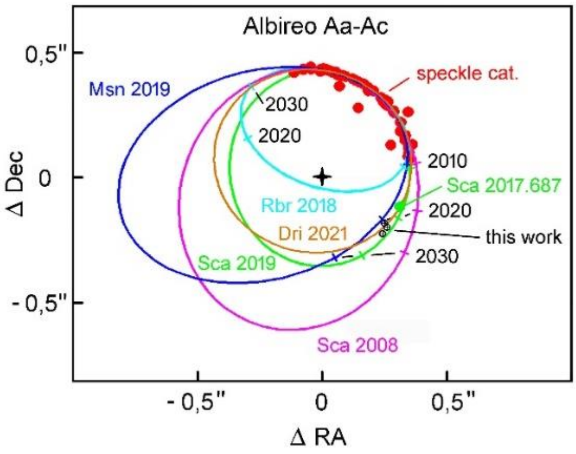


Fig. 4: Recent orbit calculations for MCA 55 Aa,Ac and observed positions. Ephemeris positions for the epochs 2010.0, 2020.0, and 2030.0 are marked on the respective orbits. Data from the speckle catalog range from 1976 until 2008 (red dots). Following is a gap until 2017.678, indicating a measurement of Scardia, which became available only in 2021 (green dot [8]). Our three speckle measurements from 2019.540, 2020.478, and 2021.574 (crossed circles) are close to the ephemeris from Mason/2019, Scardia/2019, and Drimmel et al./2021. North is down

Figure 5 shows a more detailed view of the position angle and separation of the pair versus time. Possibly, a refined orbit calculation may lay between the ones from Mason and from Drimmel. More observations in the future will help to clarify the situation.

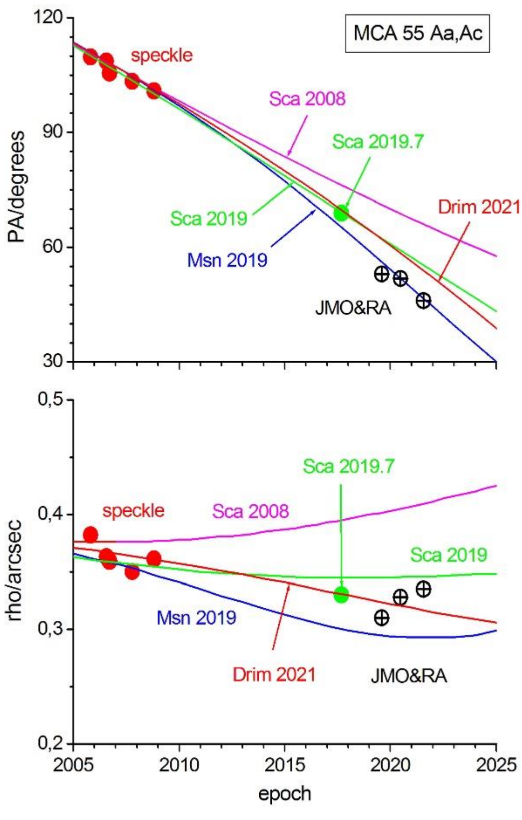


Fig. 5: Evolution with time of observed and calculated position angles and separations of MCA 55 Aa,Ac in the recent 20 years. Meaning of the symbols and curves is as in fig. 4

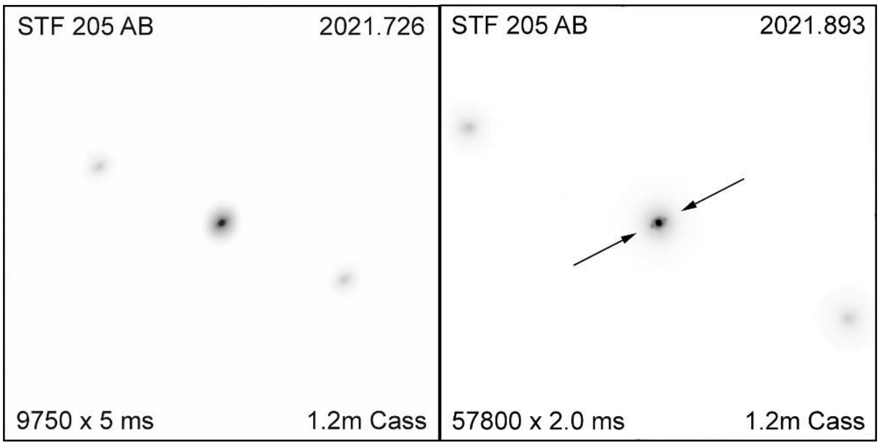
STF 205 A,BC/STT 38 BC (γ And)

Somehow similar to the case of Albireo, γ Andromedae A-BC is often believed to be a physical system, but the parallaxes of A and BC are rather different: Component A is not listed in Gaia, but Hipparcos gives a distance of 355 ly, while that of BC is 270 ± 20 ly according to Gaia eDR3, although the close pair is not resolved. Literature data of the apparent separation of A-BC exhibit some scatter around about 9.6", at least in the last few decades [3,11]. In fact, the last entry in the WDS (see table 2 below), seems to be a little too large, when compared with the trend of past speckle measurements.

Table 2: Reference data for γ And from the "WDSprecise" as of Feb. 2022 [3]:

name	RA & Dec	mag	Spectrum	P.A./deg	rho/arcsec	date
STF 205 A,BC	02039+4220	2.31 5.02	K3IIb,B+A	63.60	9.81 (?)	2020
STT 38 BC		5.3 6.5	B8V+A0V	95.70	0.219	2010

We observed the γ And system on Sept. 22nd, 2021, and on Nov. 22nd, 2021, always using a Cousins-I-filter. In September, recordings were done with and without Barlow, in order to deduce the magnification of the lens. Recordings in November were produced with Barlow. Figures 6 and 7 show representative speckle autocorrelation images of AB with both configurations.



Figs. 6 (left) and 7 (right): Speckle autocorrelation of γ And AB recorded without Barlow (fig. 6, left) and with Barlow (fig. 7, right) at the dates indicated at upper right. At this image scale (which is the same in both images), component B (=BC) is barely resolved without Barlow, but clearly seen with Barlow (arrows)

Without Barlow, the separation of AB would be 9.47" ± 0.01", when using the calibration factor as determined from Albireo AB. This result corresponds reasonably well with the trend of recent catalog data [3,11], which, however, exhibit some scatter. In particular, it differs from the catalog value from 2020 (see table 2). Nevertheless, it will be argued below that our image scale appears to be trustworthy. Anyway, by comparing with the mean of two recordings with Barlow, made at the two dates, the magnification factor was determined as 1.58.

The companion to γ And A, **STT 38 BC** is a close binary with period 62.6 years. Its orbit is highly eccentric and highly inclined, according to calculations by J. Docobo from 2017 [4]. The last entry in the WDS gives a separation of 0.219" for 2010, which, according to the ephemeris, went below 0.01" between 2012 and 2018. So it was not resolvable for most visual observers.

Recordings made at the two dates given above were processed by enhancing the contrast and re-sampling by 4 x 4. The series with 23725 and 27600 frames, respectively were subdivided into several sections, which were analyzed separately. Taking into account the calibration factor as above, and the offset of the camera orientation, the measured position angles and separations are 119.5º/ 0.312", and

118.4º/0.329”, with error margins of about ± 1.8º and ± 0.01”, respectively. The result from the latter date is shown in figure 8. Both positions seem to deviate from the ephemeris, as can be seen in figure 9 below. Similar to many other, earlier visual measurements in that part of the orbit, component C appears to move faster than expected. It would be interesting, whether this would be confirmed by more observations in the near future.

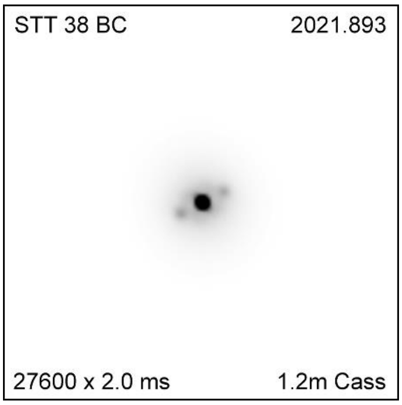


Figure 8: Speckle autocorrelation of a section of 27600 frames after 2x2 re-sampling of a recording of STT 38 BC done on 2021.89 with the QHY 174M camera and with Barlow. Image scale increased

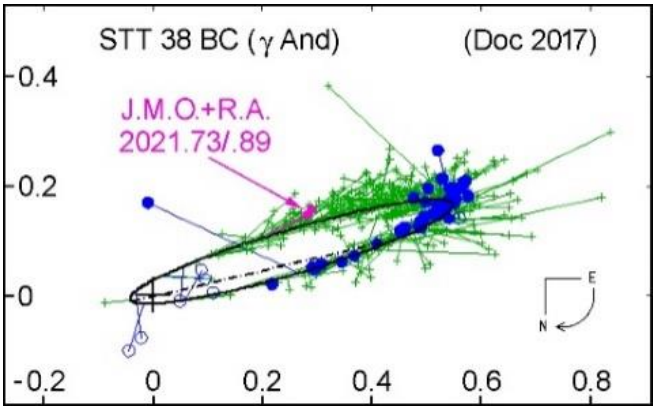


Fig. 9: The orbit of STT 38 BC with observed positions. Plot adopted from the Sixth Catalog of Orbits of Visual Binary Stars [4]). Speckle measurements are marked in blue, visual measurements in green. Our results are indicated in magenta. A line connects to the ephemeris of the corresponding dates. It seems that component C is moving somewhat faster than expected, which also appears to be the case for many other data points at least in that part of the orbit

STF 3050 AB (in Andromeda)

This binary was chosen, because it has frequently been studied in the past, and Gaia has delivered accurate position data, which could help in confirming our image scale. There are two recent orbit calculations by Hartkopf in 2011, and by Izmailov in 2019 [4]. Predicted periods are 717 years and 573 years, respectively. The orbits are graded 4 or 3, while less than one half is covered with measurements. Table 3 contains the last entry in the WDS catalog [3].

Table 3: Reference data for STF 3050AB from the “WDSprecise” catalog as of Feb. 2022 [3]:

name	RA & Dec	mag	P.A./deg	rho/arcsec	date
STF 3050 AB	23595+3343	6.46 6.72	342.10	2.480	2020

A series of 21600 speckle images was recorded at date 2021.893. A representative result of speckle autocorrelation from a section of 10000 frames is shown in figure 10.

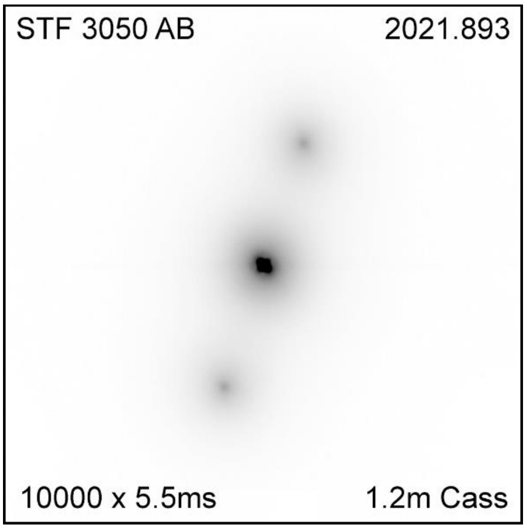


Fig. 10: Speckle autocorrelation of STF 3050 AB. Result from 10000 frames à 5.5 ms

From several such sections with about 10000 frames each, and using the calibration factor as above, mean values of the position angle and separation were found as 343.3º ± 0.1º and 2.564" ± 0.017", respectively. In fact, the PA agrees very well with the ephemeris of recent orbit calculations. However, the measured separation appears to be greater by about 0.05" than the ephemeris. See figure 11.

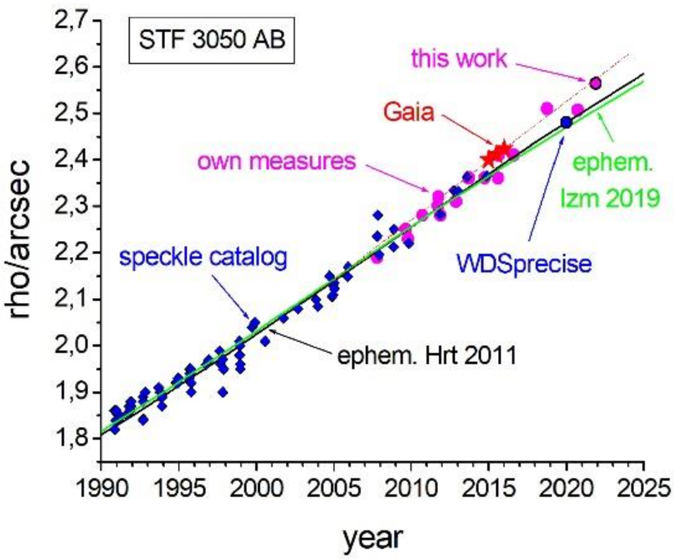


Fig. 11: Plot of the recent evolution with time of the separation of STF 3050 AB. Blue squares are from the speckle catalog [10], the black circle filled in blue is from the WDSprecise catalog [3], solid lines are from orbit calculations by Hartkopf (black) and Izmailov (green) [4]. Dots in magenta are own measures by lucky imaging with a 10" Newtonian, while the black circle filled in magenta indicates our present result from speckle interferometry. Red stars mark separations calculated from Gaia DR1, DR2, eDR3 [1], and the dotted red line indicates a tentative linear extrapolation

Also, the separations of AB, as calculated from Gaia data, clearly differ from both ephemeris calculations. In contrast, the position angles correspond quite well. Together with preceding speckle measurements, a virtually linear increase of rho is suggested for the present time. A reduction of the rate may be expected, as component B is slowly approaching periastron in 2100 (Hartkopf) or already in 2055 (Izmailov), but this could temporarily be compensated by an increase of the velocity along the orbit. In any case, a probably slight refinement of the ephemeris may be adequate.

STF 228 And

This pair is a rather well observed binary with a period 145.4 years, according to a recent calculation by J.-L. Prieur et al. in 2017 [4]. The whole orbit is covered with measurements, and its grade is classified as 2 (“good”). In table 4, the last entry in the WDS is listed [3]. The separation is currently decreasing, and will remain below 0.5” until 2043. The pair is also listed in Gaia eDR3, but for component B with a large error margin, and the calculated separation of 1.37” is obviously far too large.

Table 4: Reference data for STF 228 from the “WDSprecise” catalog as of Feb. 2022:

name	RA & Dec	mag	P.A./deg	rho/arcsec	date
STF 228	02140+4729	6.56 7.21	307.60	0.571	2018

Figure 12 shows our result from speckle autocorrelation of 34000 frames à 7.0 ms recorded at date 2021.893. Analysis of the spot pattern yields a position angle and separation of the pair as 314.1º ± 0.1º and 0.523” ± 0.01”, respectively. This position is added to the plot of the orbit, which is shown in figure 13 below. It virtually agrees with the ephemeris within the errors of the measurements: 314.08º and 0.529”.

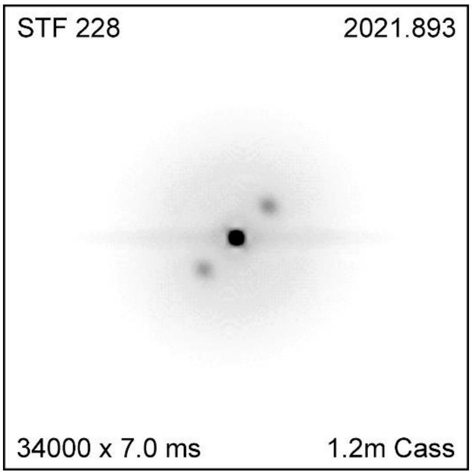


Fig. 12: Speckle autocorrelation of STF 228 And. Result from 34000 frames à 7.0 ms recorded at the date as indicated at upper right. Image scale as in fig. 8

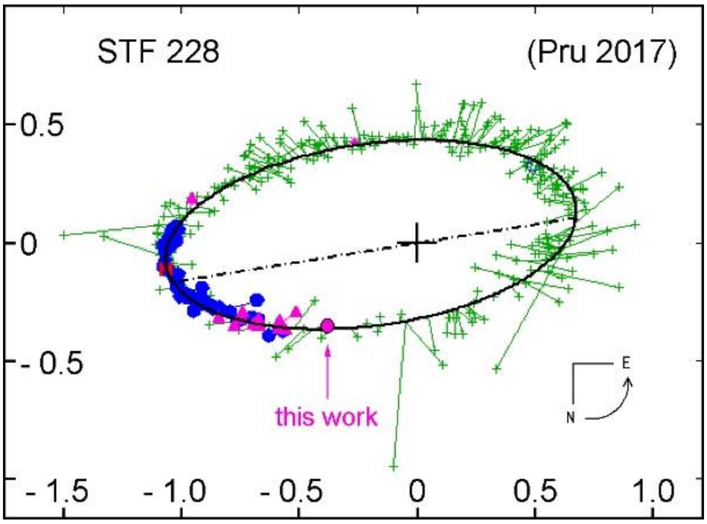


Fig. 13: Plot of the orbit of STF 228 And together with observed positions. Green: visual, blue: speckle measurements (adopted from the Sixth Catalog of Orbits of Visual Binary Stars [4]). Black circle filled in magenta indicates our present result from speckle interferometry

STT 515 AB (φ And)

This pair is also a well-known binary, and according to a calculation of its orbit by Muterspaugh in 2010 [4], the period would be 554 years. However, the grade of the orbit is only 4 ("preliminary"), as not more than about one half is covered with measurements. The separation is expected to never exceed 1 arcsec. In table 5, the actual entry in the WDS is listed. Our result from speckle imaging on Nov. 22nd, 2021, is shown in figure 14. Again, a series of about 69000 frames was subdivided into several sections, which were separately processed.

Table 5: Reference data for STT 515 AB from the "WDSprecise" catalog as of Feb. 2022:

name	RA & Dec	mag	P.A./deg	rho/arcsec	date
STT 515 AB	01095+4715	4.59 5.61	114.90	0.580	2016

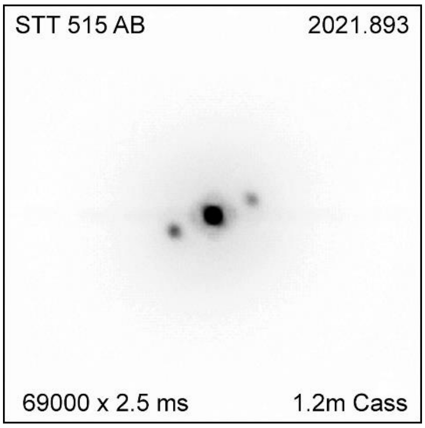


Fig. 14: Speckle autocorrelation of STT 515 AB. Result from 69000 frames à 2.5 ms recorded at the date as indicated at upper right. Image scale as in figs. 8 and 12

Analysis of the spot pattern resulted in 113.5° ± 0.4° and 0.518" ± 0.002" for the position angle and separation, respectively. This position is very close to the ephemeris of the corresponding date, as can be seen in the plot of the orbit in figure 15.

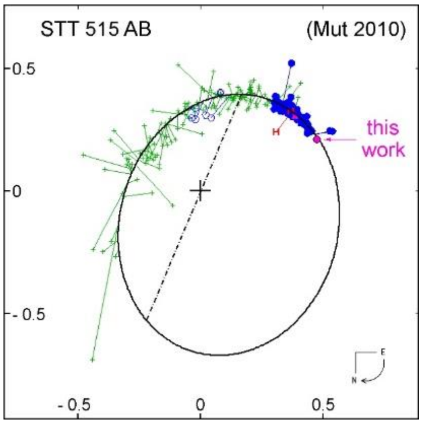


Figure 15: The orbit of STT 515 AB, as calculated by Mutersphaugh (2010), and observed position. Plot adopted from the Sixth Catalog of Orbits of Visual Binary Stars [4]. The meaning of the symbols is as above

5. Summary

Table 6 is a summary of our measurements. Starting with a nominal value of the image scale calculated from the focal length of the telescope and the pixel size of the camera, the resulting separations were compared with literature data for the respective pairs, either extrapolated, or calculated from the ephemeris for the respective epoch, as described above. The main reference was Albireo AB, as positions from Gaia and the extrapolation to the actual epoch appear rather trustworthy. This resulted in a calibration factor of 0.1272 arcsec/pixel for all measurements made without Barlow. In a second step, the magnification of the Barlow lens was determined by comparing measurements of the pair γ And AB without and with Barlow. This led to an image scale of 0.08051 arcsec/pixel for the latter case.

The reliability of these values was further checked by measuring a few other pairs with reasonably well documented separations, namely STF 3050, STT 228, and STF 515, which all agreed reasonably well with expected values, i.e. trends from Gaia or from established ephemeris data.

We conclude that

- for STFA 43 (Albireo), the separation of AB given in the WDS for 2020 probably is too large,

- our measurement of MCA 55 Aa,Ac is close to recent orbit calculations by various authors, but these are still preliminary,

- for STF 205 A,BC (γ And), the separation given in the WDS for 2020 probably is too large,

- the orbits of STT 38 BC and of STF 3050 AB should probably be refined.

Table 6: List of PA and rho measurements from speckle interferometry in this work. PA and rho figures are mean values from several recordings with and without Barlow, respectively. Error margins are standard deviations. The shaded line indicates Albireo AB, of which the extrapolated position from Gaia was taken as reference. Residuals ΔPA and Δrho refer to extrapolated literature data (see text).

name	RA & Dec	mag	PA/deg	ΔPA	rho/arcsec	Δrho	date
STT 515 AB	01095+4715	4.59 5.61	113.5 ± 0.4	+ 0.5	0.519 ± 0.002	- 0.006	2021.89
STF 205 A,BC	02039+4220	2.31 5.02	63.2 ± 0.1	- 0.4	9.470 ± 0.007	- 0.34?	2021.73
			63.2 ± 0.1	- 0.4	9.470 ± 0.011	- 0.34?	2021.89
STT 38 BC		5.3 6.5	119.5 ± 1.8	-	0.312 ± 0.010	-	2021.89
			118.4 ± 1.5	-	0.329 ± 0.005	-	2021.89
STF 228	02140+4729	6.56 7.21	314.1 ± 0.1	~ 0.0	0.532 ± 0.010	+ 0.003	2021.89

STFA 43 AB	19307+2758	3.19 4.68	54.0 ± 0.1	0!	34.65 ± 0.05	0!	2021.57
MCA 55 AaAc		3.37 5.16	46.0 ± 2.0	-	0.335 ± 0.015	-	2021.57
STF 3050 AB	23595+3343	6.46 6.72	343.3 ± 0.1	- 0.1	2.564 ± 0.017	+0.05?	2021.89

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