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# The speckle interferometric multiplicity of T Tauri type stars in the Taurus-Auriga star-forming region

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**Abstract.** We present the results of a multiplicity study of T Tau-type stars in the Taurus-Auriga association. The observational data were obtained by speckle interferometry at the 6-meter telescope of the SAO RAS in 2020 and 2024. For the resolved stars, the positional parameters of the components, as well as the magnitude differences, were determined using the reference-independent power spectrum modeling method. Among the sample containing 58 bright stars ($m_V \leq 10$ mag), 12 binary, 5 triple and one quadruple speckle-interferometric systems were detected.

**Keywords:** stars: pre-main sequence; techniques: high angular resolution

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# 1 Introduction

The Taurus-Auriga association is the closest star-forming region to the Sun (about 140 parsecs, Kenyon et al. 1994). Extending widely across the northern sky (total area about 100 degrees), Taurus-Auriga contains many T Tauri type stars (TTs). These are low-mass objects ($0.5M_{\odot}$ – $2M_{\odot}$) characterized by regular and irregular variations in luminosity, as well as a strong emission in the UV and X-ray due to accretion. As a rule, the spectral classes of these stars are between G and K (Petrov 2003).

Tau-Aur is known to be a low stellar density region with a large number of double stars, especially wide pairs, compared to field stars and star-forming regions with higher stellar densities (Joncour et al. 2017).

In the paper of Leinert et al. (1993), a sample of 104 TTs was studied using various methods, including IR speckle interferometry, among which 57.7 % were unresolved stars, 37.5 % were binary, 2.9 % were triple, and 1.9 % were quadruple. No difference was statistically detected between the multiplicity of classic TTs and weak-lined TTs. The Köhler & Leinert (1998) survey, despite the smaller sample size, confirmed the Leinert et al. (1993) values obtained.

Such surveys make it possible not just to learn the multiplicity statistics in a given star-formation region. Information on positional parameters at different observational epochs allows us to calculate orbital solutions (e.g., the works of Woitas et al. 2001; Schaefer et al. 2014, etc.), which can then be used to directly and independently estimate the masses of the systems. This is very important for young stars because theoretical evolutionary models, while differing among themselves, introduce methodological uncertainties in the mass determinations.

This paper also presents a survey of the brightest TTs, using the speckle interferometry method. We present the calculated positional parameters for the double systems, as well as an estimate of the speckle interferometric multiplicity of the sample we used.

## 2 Observations

We compiled a sample of 58 T Tauri-type stars towards the Taurus-Auriga star formation region, selected by the brightness criterion ($m_V \leq 10$ mag). Observational data were obtained at the BTA speckle interferometer of SAO RAS based on the Andor iXon Ultra 897 EMCCD detector (Maksimov et al. 2009) in October–November 2020 and January 2024. Repeated observations were necessary to confirm the separation of the components, as well as to obtain new positional parameters.

The standard observational data series contained 2000 speckle interferograms of 512x512 pixels, recorded with an exposure time of 20 milliseconds, using the following interference filters (central wavelength/bandpass): 550/20, 550/50, 700/50, 800/100, 900/80 nm.

The brightness criterion, relying on the speckle interferometer characteristics, provides the possibility of a confident observation of speckles of bright TTs with a high signal-to-noise ratio, as well as the detection of faint components of TTs with a large magnitude differences (up to 6 mag).

The observational data series were used to compute average power spectra and autocorrelation functions (ACFs) (Labeyrie 1970). An example of the autocorrelation function is shown in Fig. 1.

After the initial calibration (taking into account the average flat- and dark-frames), the most accurate model description was selected for each power spectrum using the least squares method. This way, the positional parameters of the components (separation $\rho$, positional angle $\theta$) for a given epoch were determined (Pluzhnik 2005). The method of splitting the power spectrum into narrow rings was used in the modeling process. Within a ring, the transfer function was considered constant. The boundaries of the rings were set individually for each spectrum. Modeling was carried out in the specified frequency range, excluding low frequencies containing the atmospheric profile, as well as noisy high frequencies.

Table 1 presents the positional parameters for the resolved binary systems. The positional angle $\theta$ is given with an accuracy of 180 degrees because of the uncertainty of the component positions on the ACF. The errors for the calculated magnitude differences correspond to the error of the model fitting, so they may be underestimated.

**Table 1.** The positional parameters for the resolved binary systems. The positional angle $\theta$ is given with an accuracy of 180 degrees because of the uncertainty of the component positions on the ACF.

| Name | Epoch | Filter | $\rho$, mas | $\sigma_\rho$, mas | $\theta \pm 180$, ° | $\sigma_\theta$, ° | $\Delta M$, mag | $\sigma_{\Delta M}$, mag |
|---|---|---|---|---|---|---|---|---|
| v969 Tau | 2020.76429 | 550 | 70 | 1 | 91.9 | 0.1 | 0.44 | 0.01 |
| | 2020.76428 | 700 | 69 | 1 | 93.1 | 0.1 | 0.57 | 0.01 |
| | 2024.08185 | 550 | 68 | 1 | 0.7 | 0.1 | 0.59 | 0.01 |
| | 2024.08186 | 700 | 68 | 1 | 0.9 | 0.1 | 0.53 | 0.01 |
| HD 25444 | 2020.76433 | 550 | 1635 | 1 | 52.0 | 0.1 | 2.55 | 0.02 |
| | 2024.08156 | 550 | 1703 | 1 | 50.8 | 0.1 | 2.32 | 0.01 |
| | 2024.08157 | 700 | 1701 | 1 | 50.8 | 0.1 | 1.89 | 0.01 |
| V1299 Tau | 2020.76436 | 550 | 298 | 1 | 70.4 | 0.1 | 0.64 | 0.01 |
| | 2024.08182 | 550 | 278 | 1 | 69.2 | 0.1 | 0.44 | 0.01 |
| | 2024.08188 | 700 | 278 | 1 | 69.3 | 0.1 | 0.40 | 0.01 |
| AG+18 338 | 2020.90334 | 700 | 285 | 1 | 23.0 | 0.1 | 4.56 | 0.04 |
| AG+18 339 | 2020.90333 | 700 | 69 | 1 | 14.1 | 0.3 | 2.42 | 0.03 |
| | 2024.08169 | 550 | 62 | 1 | 354.6 | 0.1 | 2.43 | 0.01 |
| HD 283798 | 2020.90662 | 800 | 1609 | 1 | 121.1 | 0.1 | 5.17 | 0.03 |
| HD 245059 | 2020.90937 | 550 | 737 | 1 | 159.7 | 0.1 | 3.23 | 0.02 |
| | 2020.90938 | 800 | 737 | 1 | 159.7 | 0.1 | 1.95 | 0.01 |
| | 2024.08214 | 550 | 716 | 1 | 161.1 | 0.1 | 3.27 | 0.01 |
| | 2024.08215 | 700 | 716 | 1 | 161.2 | 0.1 | 2.54 | 0.01 |
| HD 245567 | 2020.90940 | 550 | 357 | 1 | 137.1 | 0.2 | 4.16 | 0.07 |
| | 2020.90940 | 800 | 357 | 1 | 136.8 | 0.1 | 3.17 | 0.04 |
| | 2024.08216 | 550 | 358 | 1 | 134.1 | 0.1 | 4.51 | 0.02 |
| | 2024.08218 | 700 | 358 | 1 | 134.5 | 0.1 | 3.79 | 0.03 |
| HD 245924 | 2020.90941 | 550 | 899 | 1 | 178.5 | 0.1 | 3.10 | 0.02 |
| | 2020.90942 | 800 | 898 | 1 | 178.4 | 0.1 | 2.23 | 0.01 |
| | 2024.08219 | 550 | 885 | 1 | 179.8 | 0.1 | 3.12 | 0.01 |
| | 2024.08220 | 700 | 884 | 1 | 179.9 | 0.1 | 2.63 | 0.01 |
| HD 294207 | 2020.90918 | 550 | 2165 | 1 | 36.7 | 0.1 | 2.39 | 0.02 |
| | 2020.90918 | 800 | 2167 | 1 | 36.8 | 0.1 | 1.55 | 0.01 |
| RW Aur | 2020.90877 | 550 | 1478 | 1 | 74.4 | 0.1 | 1.92 | 0.02 |
| | 2020.90878 | 800 | 1474 | 1 | 74.4 | 0.1 | 0.81 | 0.01 |
| HD 31281 | 2020.90667 | 800 | 19 | 1 | 4.2 | 0.2 | 1.00 | 0.04 |
| | 2020.90666 | 550 | 16 | 1 | 177.5 | 0.1 | 1.42 | 0.07 |
| HD 284065 | 2020.90876 | 800 | 16 | 1 | 0.0 | 0.2 | 2.38 | 0.02 |
| | 2024.07952 | 700 | 21 | 1 | 60.7 | 0.1 | 1.44 | 0.02 |
| HD 280583 | 2020.90882 | 550 | 96 | 1 | 72.3 | 0.1 | 2.59 | 0.02 |
| | 2020.90883 | 800 | 98 | 1 | 71.8 | 0.1 | 2.70 | 0.03 |
| | 2024.07953 | 550 | 112 | 1 | 64.9 | 0.1 | 2.77 | 0.01 |
| | 2024.07954 | 700 | 108 | 1 | 65.5 | 0.1 | 2.79 | 0.03 |

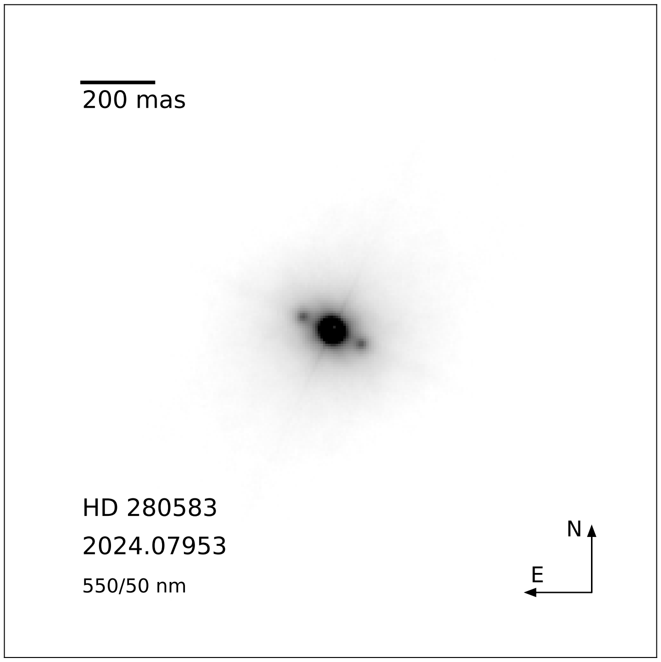

**Fig. 1.** The central part of the autocorrelation function for the system HD 280583.

## 3 Conclusion

From a sample of 58 T Tauri type stars selected by the brightness criterion ($m_V \leq 10$ mag), 19 stars were resolved into individual components. Among them, there are 12 binary, 5 triple and one quadruple speckle interferometric system. For each resolved binary system, the positional parameters of their components, as well as the magnitude differences, were obtained by the power spectra modeling (Labeyrie 1970).

The star AG+18 339 is a companion of the star AG+18 338. Each of these stars is resolved as a speckle-interferometric binary. Thus, this system is defined as a quadruple system.

Based on the above results of the processing of the observations, the estimate of the sampling speckle interferometric multiplicity is as follows: of the 58 stars, 68 % are unresolved, 21 % are binary, 9 % are triple and 2 % are quadruple.

Comparing the results with previously mentioned multiplicity surveys (e.g., Leinert et al. 1993), there are differences in the multiplicity percentages due to the different observational methods used. Nevertheless, despite the smaller sample size in this paper, it can be seen that a relatively high percentage of higher-order multiplicity systems are observed for the included stars.

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