Speckle Interferometry of Nearby Multiple Stars. IV. Measurements in 2004 and New Orbits

I.I. Balega1, Yu.Yu. Balega1, A.F. Maksimov1, E.V. Malogolovets1, D.A. Rastegaev1, Z.U. Shkhagosheva1, G. Weigelt2

1 Special Astrophysical Observatory, RAS, Nizhnii Arkhyz, Karachai-Cherkessian Republic, 357147 Russia
2 Max-Planck Institut für Radioastronomie, Bonn, Germany

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Abstract. The results of speckle interferometric observations of 104 binary and 6 triple stars performed at the BTA 6 m telescope in 2004 October are presented. Nearby low-mass stars are mostly observed for the program, among which 59 there are new binaries recently discovered by the Hipparcos astrometric satellite. Concurrently with the diffraction-limited position measurements we obtained 154 brightness ratio measurements of binary and multiple star components in different bands of the visible spectrum. New, first-resolved binaries are the symbiotic star CH Cyg with a weak companion at 0.043″ separation and the pair of red dwarfs, GJ 913 = HIP 118212. In addition, we derived the orbital parameters for two interferometric systems: the CN-giant pair HD 210211 = HIP 109281 (P = 10.7 yr) and the G2V-K2V binary GJ 9830 = HIP 116259 (P = 15.7 yr).

1. INTRODUCTION

This is the fourth paper in the series of publications with the data on speckle interferometry observations of binary and multiple stars performed with the BTA 6 m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences using a new detector system based on a 3-stage image intensifier and a fast CCD (Maksimov et al., 2003). The main objects of the program are nearby low-mass stars with a considerable, of the order of $10^5$ yr, relative motion of the components, which makes them good new candidates for the calculation of visible orbits. Around half of these stars are new binaries discovered by the Hipparcos astrometric satellite (Perryman, 1997). The regular speckle interferometric observations of new Hipparcos binaries have been carried out at the BTA telescope since 1998 (Balega et al., 2002, Balega et al., 2004, Balega et al., 2006a). In addition, some early-type systems that are interesting for interferometric monitoring were included in the program. In particular, the Orion Trapezium members were observed in the visible range to reveal the relative motion of the components.

2. OBSERVATIONS AND RESULTS

The measurements are derived from speckle interferometry (Labeyrie, 1970) observations taken at the BTA 6 m telescope of the Special Astrophysical Observatory during the period October 23 through November 1, 2004. During the observing period, the seeing changed between 1″ and 5″. On October 25/26, the seeing was 0.8″–1″. Note that even in the nights of poor seeing, speckle interferometry allowed us to perform speckle measurements of bright stars with a diffraction-limited angular resolution.

The instrumentation, observing procedure, data reduction, and calibration have already been described in the previous papers of this series (Balega et al., 2002, Balega et al., 2004, Balega et al., 2006a). The high sensitivity of the detector allows us to measure stars up to the 15th magnitude with a diffraction-limited resolution.

In this paper the results of 181 measurements of the relative positions of 104 binary stars (Table 1) and single measurements for 6 triple stars (Table 2) are presented. For each system the tables give four identifier numbers (the Hipparcos Catalog number, the name or the number from other catalogs, the discoverer designation, and the Washington Double Star Catalog coordinates, J2000.0). The identifier numbers are followed by the observation date as a fraction of the Besselian year, the measured position angle $\theta$ in degrees and its error $\sigma_{\theta}$, the measured angular distance $\rho$ in milliarcseconds (mas) and its error $\sigma_{\rho}$, the observed magnitudes difference $\Delta m$ and its uncertainty $\sigma_{\Delta m}$.
the center wavelength $\lambda$ of the filter used to make the observation (nm), and the FWHM of the filter passband $\Delta\lambda$. For triple stars, Table 2 presents also the designations of the subsystems. The measured distances between the components of the systems range from 23 mas for $\theta^1$ Ori C to 1622 mas for HIP 103810. The separation accuracy depends on many parameters; first of all, on the atmospheric conditions. For the majority of measurements, it is equal to 2–3 mas; however, for the most wide pairs with a separation of $> 1''$, the error may reach 6–8 mas. The errors of the position angle measurements are $0.3^\circ$–$1.0^\circ$. Comments on the measurements of individual stars are given in the next section.

It is known that in speckle interferometry, the ensemble average modulus of the Fourier transform of a series of speckle images defines the position angles of binary stars with a $\pm 180^\circ$ ambiguity. To avoid this uncertainty, it is necessary to reconstruct not only the modulus but also the phase of the observed source (Weigelt, 1977; Lohmann et al., 1983). This requires a large number of additional computations. In binary star speckle interferometry, we solve the problem of position angles using a simple approach proposed by Walker (Walker, 1981). In this method we calculate the modulus of the Fourier transform of the product of the speckle interferograms and an exponential in addition to the measured modulus of the Fourier transform. From the measurements of the two moduli the location of the complex zeros of the analytical continuation of the Fourier transform of the unknown image can be found and the true image of a binary reconstructed. Problems arise when the components of a binary have similar magnitudes or when the differential speckle photometry of the pair is seriously noise-limited. The $\theta$ measurements with the $\pm 180^\circ$ ambiguity are marked with asterisks in Table 1.

Table 1: Double star measurements

| HIP No. | Name/ Catalog No. | Discoverer designation | Coord. 2000.0 | Epoch 2004.0+ | $\theta$, deg | $\sigma_\theta$, mas | $\rho_1$, mas | $\rho_2$, mas | $\Delta m$ | $\sigma_{\Delta m}$ | $\lambda/\Delta\lambda$, nm |
|---------|------------------|-----------------------|--------------|--------------|----------------|----------------|--------------|--------------|-------------|----------------|-----------------------------|
| 68 | BD+16 5027 | BAG 18 | 00008+1659 | .8318 | 22.3 | 0.3 | 560 | 2 | 2.68 | 0.04 | 800/110 |
| 201 | HD 225000 | HDS 2 | 00026+1841 | .8372 | 123.3* | 1.0 | 80 | 2 | 2.34 | 0.05 | 545/30 |
| 689 | HD 375 | HDS 17 | 00085+3456 | .8237 | 347.9 | 0.5 | 64 | 2 | 0.20 | 0.04 | 600/30 |
| 823 | HD 23 | HDS 23 | 00101+3825 | .8237 | 91.7* | 1.18 | 72 | 2 | 0.00 | 0.21 | 800/110 |
| 1055 | BD+19 20 | HDS 29 | 00132+2023 | .8238 | 169.0 | 0.3 | 664 | 2 | 1.11 | 0.06 | 800/110 |
| 1987 | HD 2057 | HDS 56 | 00252+4803 | .8265 | 149.0* | 1.1 | 238 | 5 | 545/30 |
| 2532 | HD 2893 | HDS 71 | 00321-1218 | .8342 | 153.7* | 0.4 | 292 | 2 | 0.41 | 0.10 | 545/30 |
| 3361 | BD+12 81 | HDS 93 | 00425+1249 | .8211 | 71.3 | 0.3 | 247 | 2 | 1.44 | 0.03 | 600/30 |
| 3669 | BD+42 170 | HDS 102 | 00469+4339 | .8320 | 125.6 | 0.6 | 152 | 2 | 1.06 | 0.03 | 800/110 |
| 4267 | ADS 746 | STT 20 | 00546+1911 | .8212 | 188.0 | 0.4 | 540 | 3 | 1.05 | 0.05 | 545/30 |
| 4809 | HD 6009 | HDS 134 | 01017+2518 | .8154 | 318.8 | 0.3 | 89 | 2 | 0.21 | 0.04 | 600/30 |
| 4849 | GJ 3071 | HDS 135 | 01024+0504 | .8155 | 135.3 | 0.3 | 275 | 2 | 1.68 | 0.03 | 600/30 |
| 5531 | HD 6840 | HDS 155 | 01108+6747 | .8155 | 159.6 | 0.3 | 116 | 2 | 0.71 | 0.02 | 545/30 |
| 5674 | HD 7169 | HDS 160 | 01129+5136 | .8373 | 54.6 | 0.4 | 181 | 2 | 2.00 | 0.02 | 545/30 |
| 5952 | HD 7640 | HDS 169 | 01166+1831 | .8238 | 247.9 | 0.4 | 639 | 4 | 3.32 | 0.17 | 600/30 |
| 6060 | ADS 1040 | STF 102 | 01178+4901 | .8265 | 273.3 | 0.4 | 475 | 3 | 0.83 | 0.13 | 545/30 |
| 7338 | HDS 211 | ADS 1040 | 01345+7804 | .8156 | 245.2 | 0.8 | 279 | 4 | 2.17 | 0.06 | 800/110 |
| 7397 | HDS 213 | ADS 1040 | 01463+4059 | .8239 | 202.0* | 0.4 | 80 | 2 | 0.00 | 0.13 | 545/30 |
| 10022 | HD 13102 | COU 1067 | 02090+3540 | .8374 | 30.2 | 0.5 | 196 | 2 | 0.00 | 0.25 | 545/30 |
| 10414 | HD 13865 | HDS 297 | 02142+0909 | .8212 | 38.9 | 0.5 | 583 | 3 | 1.32 | 0.05 | 800/110 |
| 10660 | HD 14874 | HDS 302 | 02172+5838 | .8374 | 243.7 | 0.5 | 392 | 3 | 2.73 | 0.09 | 545/30 |
| 11253 | HD 14874 | HDS 314 | 02249+3039 | .8239 | 276.9 | 0.3 | 372 | 2 | 2.68 | 0.05 | 545/30 |
| 11352 | HD 15013 | HDS 318 | 02262+3428 | .8157 | 185.4 | 0.4 | 124 | 2 | 0.00 | 0.17 | 600/30 |
| 11474 | HR 719 | KUI 8 | 02280+0158 | .8213 | 37.3 | 0.3 | 502 | 3 | 0.25 | 0.04 | 545/30 |

or when the differential speckle photometry of the pair is seriously noise-limited. The $\theta$ measurements with the $\pm 180^\circ$ ambiguity are marked with asterisks in Table 1.
| HIP No. | Name/Catalog No. | Discoverer | Coord. 2000.0 | Epoch 2004.0± | θ, deg | σθ, mas | ρ, mas | σρ, mas | Δm | σΔm | λ/Δλ, nm |
|--------|-----------------|------------|---------------|---------------|--------|---------|--------|---------|-----|------|---------|
| 12495  | ADS 2018 Aa     | CHR 208   | 02407+6117   | .8264         | 269.2+  | 0.7     | 289    | 3       | 0.65| 0.06| 545/30  |
| 12552  | HD 16656        | COU 1511  | 02415+4053   | .8374         | 65.0    | 0.7     | 135    | 2       | 0.65| 0.06| 545/30  |
| 13308  | ADS 2165        | BU 1316   | 02512+6023   | .8264         | 297.7+  | 0.5     | 317    | 3       |      |      | 545/30  |
| 14075  | HD 18774        | HDS 385   | 03014+0615   | .8157         | 166.2   | 0.4     | 162    | 2       | 0.00| 0.17| 800/110 |
| 14230  | HD 18940        | HDS 389   | 03035+2304   | .8157         | 23.1    | 0.5     | 76     | 2       | 1.73| 0.06| 545/30  |
| 14669  | GJ 125          | HDS 404   | 03095+4544   | .8213         | 240.5   | 0.3     | 83     | 2       | 1.59| 0.05| 800/110 |
| 14864  | GJ 3206         | HDS 407   | 03119+6131   | .8214         | 156.3   | 0.3     | 600    | 2       | 1.51| 0.03| 800/110 |
| 14929  | HD 19895        | HDS 408   | 03125+1857   | .8158         | 122.0   | 1.6     | 26     | 2       | 0.00| 0.36| 545/30  |
| 15309  | ADS 2436        | STT 52    | 03175+6540   | .8156         | 59.1    | 0.4     | 485    | 2       | 0.45| 0.05| 545/30  |
| 15737  | 63 Ari          | HDS 423   | 03228+2045   | .8267         | 292.9   | 0.5     | 416    | 4       | 3.36| 0.12| 700/30  |
| 16025  | HD 21183        | HDS 430   | 03264+3520   | .8158         | 244.2   | 0.4     | 279    | 2       | 1.76| 0.03| 545/30  |
| 18089  | 31 Tau          | KUI 15    | 03519+0633   | .8159         | 207.0   | 0.4     | 75     | 2       | 0.31| 0.05| 545/30  |
| 18370  | HD 24431        | HDS 494   | 03556+5238   | .8266         | 177.7+  | 0.4     | 723    | 5       |      |      | 545/30  |
| 18856  | BD+06 620       | HDS 510   | 04025+0638   | .8214         | 150.3   | 0.7     | 77     | 2       | 0.28| 0.05| 800/110 |
| 19206  | HD 25811        | BAG 4     | 04063+1952   | .8158         | 229.0   | 0.9     | 74     | 2       | 0.24| 0.27| 545/30  |
| 19270  | SZ Cam          | CHR 209   | 04078+6220   | .8216         | 115.6   | 0.3     | 75     | 2       | 0.95| 0.02| 545/30  |
| 19472  | HD 285465       | HEI 35    | 04102+1722   | .8241         | 343.4   | 0.3     | 323    | 2       | 1.29| 0.04| 600/30  |
| 19591  | HD 284163       | CHR 14    | 04119+2338   | .8214         | 5.7     | 0.3     | 280    | 2       | 1.24| 0.02| 800/110 |
| 20553  | HD 27836        | HDS 564   | 04242+1445   | .8159         | 247.2   | 0.4     | 302    | 2       | 2.24| 0.04| 800/110 |
| 20777  | DF Tau          | THB 1     | 04270+2542   | .8215         | 247.1   | 0.5     | 108    | 2       | 0.60| 0.03| 800/110 |
| 20895  | HD 283646       | HDS 576   | 04287+2613   | .8241         | 140.4   | 0.5     | 147    | 2       | 0.18| 0.14| 800/110 |
| 21280  | HD 285931       | CHR 17    | 04340+1510   | .8160         | 271.1   | 0.4     | 192    | 2       | 1.05| 0.04| 800/110 |
| 21762  | HD 29068        | CHR 154   | 04404+1631   | .8242         | 44.2    | 0.3     | 226    | 2       | 1.35| 0.03| 800/110 |
| 21881  | 94 Tau          | MCA 16    | 04422+2257   | .8242         | 44.0    | 0.4     | 303    | 2       | 2.48| 0.02| 545/30  |
| 22550  | ADS 3475        | BU 883    | 04512+1104   | .8241         | 55.6    | 0.3     | 96     | 2       | 0.00| 0.11| 545/30  |
| 23699  | HD 32641        | STT 97    | 05056+2304   | .8161         | 149.5   | 0.4     | 356    | 3       | 1.34| 0.08| 545/30  |
| 23772  | HD 240622       | HDS 666   | 05066+2630   | .8268         | 207.4+  | 1.6     | 169    | 5       |      |      | 800/110 |
| 25499  | 115 Tau         | MCA 19    | 05272+1758   | .8269         | 94.7+   | 0.4     | 88     | 2       | 0.95| 0.02| 545/30  |
| 25565  | IU Aur          | HDS 721   | 05279+3447   | .8268         | 49.4+   | 1.4     | 141    | 4       | 1.70| 0.11| 545/30  |
| 25733  | ADS 4072        | HU 217    | 05297+3523   | .8268         | 253.9   | 0.4     | 604    | 3       | 1.70| 0.11| 545/30  |
| 26220  | θ1 Ori A        | PTR 1     | 05333-0523   | .8161         | 0.3     | 1.6     | 203    | 2       | 2.66| 0.13| 800/110 |
| 26221  | θ1 Ori C        | WGT 1     | 05353-0523   | .8216         | 189.8   | 2.4     | 23     | 2       | 1.06| 0.11| 545/30  |
| HIP No. | Name/ Catalog No. | Discoverer designation | Coord. 2000.0 | Epoch 2004.0+ | $\theta$, deg | $\sigma_\theta, \rho_\sigma$ | $\sigma_p, \Delta m$ | $\Delta \lambda/\Delta \lambda_*$ | $\lambda/\Delta \lambda_*$ |
|---------|-------------------|-----------------------|---------------|---------------|---------------|-----------------|-----------------|-------------------|-------------------|
| 29269   | HD 39861          | HDS 841               | 06102+8131    | .8270         | 197.5         | 0.5 654         | 5 800/110        |                   |                   |
| 30272   | ADS 4950 AB       | STF 881               | 06221+5922    | .8270         | 143.1         | 0.3 657         | 2 700/30         |                   |                   |
| 30920   | GJ 234            | B 2601                | 06294-0249    | .8217         | 37.1          | 0.3 1359        | 3 2.77* 0.03     | 800/110           |                   |
| 32132   | BD+40 1685        | HDS 930               | 06426+3955    | .8244         | 20.4*         | 0.6 88          | 2 0.00 0.18      | 545/30            |                   |
| 32313   | GJ 2050           | BAG 22                | 06448+7153    | .8271         | 69.1*         | 0.7 545         | 7 800/110        |                   |                   |
| 35457   | HD 56099          | HDS 1018              | 07192+5908    | .8272         | 16.8*         | 0.4 130         | 2 0.00 0.23      | 545/30            |                   |
| 38619   | HDS 1123          | 07545+6008            | .8272         | 178.5*        | 0.5 688        | 6 800/110        |                   |                   |
| 39261   | 53 Cam            | MCA 33                | 08017+6019    | .8243         | 305.3         | 0.7 90          | 2 1.41 0.02      | 545/30            |                   |
| 39402   | HDS 1149          | 08033+5251            | .8243         | 207.3         | 0.3 265        | 2 0.00 0.16      | 800/110           |                   |
| 46199   | HD 81105          | HDS 1353              | 09252+4606    | .8244         | 153.7         | 0.3 361         | 2 2.48 0.03      | 600/30            |                   |
| 94679   | ADS 12239 AB      | STT 371               | 19159+2727    | .8231         | 160.4         | 0.3 881         | 2 0.27 0.20      | 545/30            |                   |
| 95178   | HD 183678         | HDS 2740              | 19218+7708    | .8261         | 2.0*          | 0.3 333         | 5 800/110        |                   |                   |
| 95413   | CH Cyg            | 19246+5014            | .8151         | 24.1          | 2.1 43         | 2 2.03 0.04      | 545/30            |                   |
| 95995   | GJ 762.1          | MCA 56                | 19311+5835    | .8150         | 75.0          | 0.3 110         | 2 0.29 0.03      | 600/30            |                   |
| 96339   | GJ 4114 A         | BAG 27                | 19351+0828    | .8232         | 3.8           | 0.3 284         | 2 0.17 0.06      | 800/110           |                   |
| 96656   | GJ 765.2          | MLR 224               | 19391+7625    | .8150         | 126.7         | 0.6 82          | 2 0.59 0.03      | 600/30            |                   |
| 97496   | ADS 12973 AB      | AGC 11                | 19490+1909    | .8149         | 28.4          | 0.4 74          | 2 0.39 0.05      | 545/30            |                   |
| 99874   | HR 7744           | MCA 60                | 20158+2749    | .8259         | 327.8         | 1.3 91          | 2 2.92 0.11      | 850/75            |                   |
| 101181  | HD 195397         | HDS 2932              | 20306+1349    | .8260         | 356.5*        | 0.8 70          | 2 0.61 0.06      | 545/30            |                   |
| 102357  | GJ 804            | CAR 2                 | 20444+1945    | .8260         | 139.5*        | 1.9 86          | 3 800/110        |                   |                   |
| 103502  | HDS 2989          | 20582+4011            | .8260         | 148.5*        | 0.5 241        | 2 1.04 0.11      | 800/110           |                   |
| 103810  | ADS 14575         | STF 2751              | 21022+5640    | .8152         | 354.3         | 1.3 1617        | 6 545/30         |                   |
| 104075  | TV Equ            | HDS 3004              | 21051+0757    | .8233         | 3.6           | 0.6 252         | 3 3.87 0.10      | 545/30            |                   |
| 104565  | GJ 4182           | BAG 29                | 21109+2925    | .8243         | 210.3         | 0.4 126         | 2 0.43 0.05      | 800/110           |                   |
| 105187  | BD+65 1572        | HDS 3032              | 21185+6613    | .8317         | 143.9         | 0.3 737         | 3 800/110        |                   |
| HIP No. | Name/ Catalog No. | Discoverer designation | Coord. 2000.0 | Epoch 2004.0 | θ, deg | σθ | ρ, mas | σρ, mas | Δm | σΔm | λ/Δλ, nm |
|--------|------------------|-----------------------|--------------|-------------|--------|-----|--------|--------|-----|-------|----------|
| 105947 | HD 204236        | HDS 3053              | 21274-0701   | .8152       | 127.5  | 0.3 | 195    | 2      | 1.47 | 0.03  | 545/30   |
| 106059 | HD 204827        | HDS 3058              | 21290+5844   | .8261       | 181.3  | 0.9 | 93     | 2      | 0.88 | 0.04  | 545/30   |
| 106866 | ADS 15184 Aa     | MIU 2                 | 21390+5729   | .8262       | 234.2  | 0.5 | 99     | 2      | 1.38 | 0.02  | 545/30   |
| 112970 | HD 216606        | HDS 3247              | 22029+1547   | .8370       | 226.0  | 1.0 | 38     | 2      | 0.51 | 0.04  | 545/30   |
| 113852 | HR 8778          | HDS 3145              | 22083+2409   | .8153       | 273.1  | 0.3 | 126    | 2      | 0.50 | 0.02  | 545/30   |
| 109951 | HD 211276        | HDS 3158              | 22161-0705   | .8152       | 92.5   | 0.3 | 357    | 2      | 1.88 | 0.03  | 545/30   |
| 112695 | HD 216027        | HDS 3241              | 22493+1517   | .8207       | 302.1  | 2.0 | 64     | 3      | 2.24 | 0.08  | 545/30   |
| 114922 | GJ 893.4         | HDS 3316              | 23167+1937   | .8153       | 275.3  | 0.5 | 126    | 2      | 0.15 | 0.17  | 800/110  |
| 114927 | BD+33 4679       | HDS 3315              | 23167+3441   | .8208       | 211.7  | 0.4 | 195    | 2      | 0.34 | 0.06  | 800/110  |
| 115666 | ADS 16748 AB     | HO 489                | 23260+2742   | .8154       | 223.0  | 0.4 | 521    | 3      | 0.00 | 0.30  | 545/30   |
| 116259 | GJ 9830          | HDS 3356              | 23334+4251   | .8236       | 152.1  | 0.6 | 99     | 2      | 2.45 | 0.03  | 545/30   |
| 116294 | HD 221630        | HDS 3357              | 23338-0508   | .8371       | 77.7   | 0.3 | 690    | 3      | 2.02 | 0.08  | 545/30   |
| 116310 | ADS 16836        | BU 720                | 23340+3120   | .8236       | 97.3   | 0.3 | 550    | 2      | 0.38 | 0.04  | 600/30   |
| 116810 | HDS 3363         | 23405+2959            | .8209       | 240.3       | 0.3   | 869   | 3      | 1.75 | 0.04  | 800/110  |
| 118212 | GJ 913           | 23587+4644            | .8210       | 74.2        | 0.9   | 62    | 2      | 1.36 | 0.03  | 850/75  |
| 118287 | ADS 17151        | A 1498                | 23595+5441   | .8209       | 87.7   | 0.3 | 375    | 2      | 0.12 | 0.06  | 545/30   |

The differential measurements of magnitude differences Δm between the components were performed concurrently with the position measurements of the major part of the studied stars. In Tables 1 and 2 we give 142 Δm values for binaries and 12 measurements for triples in different bands. The uncertainty of the Δm estimates varies from 0.02 to 0.37 magnitudes. Photometric measurements are more sensitive to seeing conditions than astrometric; therefore, Δm could not be derived with a seeing worse than 2′′. The main problem of differential speckle photometry with the bad seeing is that the star partially falls outside the detector’s window (3′′). The same difficulties arise during observations of wide pairs with ρ > 1′′. An example is GJ 234, whose measurements of Δm are marked with asterisks and probably overestimated because the frame window cuts the speckle images.

So far, 12 orbits for new Hipparcos binaries have been published based on speckle interferometry with the BTA telescope (Balega et al., 2005; Balega et al., 2006b). Using the 2004 observations and the newest 2006 measurements, we can derive orbital parameters for two more Hipparcos binaries: HIP 109281 and HIP 116259. The method of orbit computation is described in our previous paper (Balega et al., 2005). New relative orbits of the systems are plotted in fig. 1 and 2 and short comments on the orbits are given in the next section.
Table 2. Triple star measurements

| HIP No. | Name/Catalog No. | Discoverer designation | Coord. 2000.0 | Epoch 2004.0+ | Comp. | θ, deg | σθ, mas | ρ, mas | σρ, mas | Δm, mas | σΔm, mas | λ/Δλ, nm |
|---------|------------------|------------------------|---------------|--------------|-------|--------|--------|--------|--------|--------|----------|----------|
| 5245    | HD 6639          | HDS 144                | 01071-0036    | .8155        | AB    | 224.7  | 0.4    | 233    | 2      | 1.75   | 0.04     | 800/110 |
|         |                  | BAG 12                 |               |              | AC    | 167.5  | 1.5    | 1223   | 6      |        |          |          |
| 101955  | GJ 795           | KUI 99                 | 20396+0458    | .8232        | AB    | 307.1  | 0.3    | 322    | 2      | 1.26   | 0.05     | 600/30   |
|         |                  | BAG 14                 |               |              | AC    | 105.2  | 0.4    | 164    | 2      | 1.44   | 0.04     |          |
|         |                  | BC                     |               |              |       | 119.8  | 0.3    | 479    | 2      | 0.18   | 0.07     |          |
| 111805  | ADS 16138        | HO 295                 | 22388+4419    | .8235        | AB    | 153.8  | 0.3    | 314    | 2      | 545/30 |          |
|         |                  | BAG 15                 |               |              | AC    | 162.2  | 10.5   | 25     | 5      |        |          |          |
|         |                  | BC                     |               |              |       | 153.1  | 1.0    | 290    | 5      |        |          |          |
| 112170  | ADS 16214        | STT 476                | 22431+4710    | .8235        | AB    | 119.6  | 0.3    | 492    | 2      | 0.35   | 0.05     | 545/30   |
|         |                  | HU 91                  |               |              | AC    | 130.7  | 0.4    | 502    | 3      | 1.20   | 0.05     |          |
|         |                  | BC                     |               |              |       | 209.1  | 1.5    | 97     | 3      | 0.86   | 0.05     |          |
| 116384  | GJ 900           | MEL 9                  | 23350+0136    | .8208        | AB    | 335.7  | 0.3    | 610    | 2      | 2.56   | 0.06     | 800/110 |
|         |                  | AC                     |               |              |       | 345.7  | 0.4    | 722    | 4      | 3.18   | 0.22     |          |
| 116726  | ADS 16904        | A 643                  | 23393+4543    | .8154        | AB    | 138.9  | 0.3    | 250    | 2      | 0.11   | 0.02     | 545/30   |
|         |                  | AC                     |               |              |       | 143.8  | 0.5    | 216    | 2      | 0.98   | 0.03     |          |
|         |                  | BC                     |               |              |       | 291.6  | 3.1    | 39     | 3      | 0.86   | 0.02     |          |

Fig. 1. Apparent ellipse representing the orbital elements for HIP 109281. The BTA speckle interferometric data are indicated by filled circles, the speckle interferometric measurements performed by Horch et al. are shown by open circles, and the Hipparcos measurement is shown as an open triangle. Residual vectors for all measurements are plotted, but in some cases they are smaller than the points themselves. The orbital motion direction is indicated by an arrow. The solid line shows the periastron position, while the dash-and-dot line represents the line of nodes. The dashed circle around the position of the primary has an angular radius of 0.02′′ corresponding to the diffraction limit of the 6 m telescope in the V band. North is up and east is to the left.

3. COMMENTS ON INDIVIDUAL STARS

HIP 5245 (see Table 1). The faint tertiary component (Bag12) in this K0 system was first found in the K band with the BTA 6 m telescope in 1999 (Balega et al., 2002). It turned out to be 3 magnitudes fainter than the main component. A very weak sign of the component at a distance of 1.2′′ from the A star was seen through the 800/110 nm filter in the 2004 observations. Its magnitude could not be estimated because of the noise in the power spectrum.

HIP 7338. Nine interferometric observations and one Hipparcos measurement of this pair of red dwarfs allowed us to confidently define half of its relative motion ellipse. The resulting orbit, with a period of 23 yrs, and the semimajor axis of a=0.20″ under \( \pi_{H_p}=28.7 \) mas gives a mass-sum of the system of 0.7 \( M_\odot \). However, the discrepancies between the measurements and the calculated positions are still very high. It is possible that the first Hipparcos observation had a large error, which may be explained by the faintness of the companion (magnitude fainter than 13.5). It will probably take a few more years to define the reliable orbit for the pair.
Our differential photometry carried out after 1999 shows that at 800 nm the magnitude difference between the components is $2.2 \pm 0.1$. Based on the parallax value $\pi_{H}$=28.7 mas, the integral visible magnitude $m_V$=10.64, and the color index $V-I$=1.35 in the Cousins system (Perryman, 1997), we derived the absolute $I$ magnitude of the secondary as $I_B$=9.0. This corresponds to the M5 spectral type. The specified differential photometry of the pair suggests a lower temperature of the secondary compared to that proposed in the first paper of the series (Balega et al., 2002).

**HIP 39402.** This is another system of M dwarfs at a distance of 31 pc from the Sun. Possibly, its orbital period is 26 yrs and the semimajor axis is 0.28″. However, the scattering of speckle data is abnormally large under this solution. We do not exclude that the significant deviations of the measurements are caused by the presence of a third star in the system, as mentioned in our 1999 observations (Balega et al., 2004).

**HIP 95413 = CH Cyg.** A symbiotic system with the M6 giant main component resolved for the first time. Presently, a generally accepted model of the system does not exist; and there is no explanation for the nature of the star’s activity. Most researchers suggest a triple model for CH Cyg: the M6III giant and a white dwarf form the inner orbit with a period of 756 days, while the third component moves in the outer orbit with a period of 14.5 yrs. The tertiary star could be a G-K dwarf or a giant (Hinkle et al., 1993; Skopal, 1995; Skopal et al., 2002). However, the photometric and spectroscopic variability of the star can also be satisfactorily interpreted by a binary model (Yamashita & Maehara, 1979; Mikolajewski et al., 1990). Detailed analysis of the model limitations from the speckle observations will be made in a separate paper. Here we draw attention to only two important details. First, at a distance of 270 pc (Viotti et al., 1997), the discovered companion can only be connected with the long-period orbit in the system. Second, the position angle of the pair ($\approx 25^\circ$) is almost perpendicular to the extended nebulosity (position angle $\approx 165^\circ$) discovered in UV continuum, [OIII] and Balmer lines with the HST WFPC2 (Eyers et al., 2002).

**HIP 99874 = 23 Vul = MCA 60.** The main component of this pair is a K3-type giant. A faint companion ($\Delta m=2.92$ in the $I$ band) is moving with acceleration in the direction of the main star in a highly inclined orbit. The pair was also observed with the BTA 6 m telescope in 2002. However, the results were never published because of bad weather conditions during the observations: 2002.7980, $\theta=326.8^\circ$, $\rho$=156 mas. The quadrants of all speckle observations collected in the 4th Catalog of Interferometric Measurements of Binary Stars (Hartkopf et al., online catalog) have to be changed by 180°. The third star in the system, CHR 94, has never been detected in our observations.

**HIP 109281.** The elements of the interferometric orbit can now be derived for this pair of evolved stars using 13 speckle measurements with the BTA 6 m telescope and the WIYN 3.5 m telescope (Horch et al., 2002), and using the first measurements by Hipparcos:

- $P = 10.736 \pm 0.078$ yrs,
- $T = 1997.812 \pm 0.025$,
- $e = 0.518 \pm 0.010$,
- $a = 0.095 \pm 0.001$",
- $i = 151.2 \pm 2.2^\circ$,
- $\Omega = 50.4 \pm 3.2^\circ$,
\( \omega = 292.5 \pm 3.2^\circ \).

Note that one new measurement with the 6 m telescope made in 2006 was used to calculate the parameters (not included in Table 1). The list of position measurements, together with the deviations from calculated values, is presented in Table 4. The graphical presentation of the orbit is shown in fig. 1. With the Hipparcos parallax value \( \pi_{\text{HP}} = 12.65 \pm 0.79 \) mas (Perryman, 1997), the mass-sum of the binary is \( \Sigma M = 3.2 \pm 0.6 \, M_\odot \) (accuracy 19\%).

**HIP 111805 = Bag 15** (see Table 2). A close companion of the main star in the triple system is resolved marginally. Nevertheless, despite the significant error of the measurement, we decided to include its \( \theta \) and \( \rho \) values in Table 2. The pair (G2V+K1V, \( P = 551 \) d) was discovered spectroscopically by Duquennoy (Duquennoy, 1987) and later resolved by speckle interferometry at the BTA telescope (Balega et al., 2002).

**HIP 116259.** The system with the G2 and K4 components (Balega et al., 2002) belongs to the old population of the Galaxy (Nordstrom et al., 2004). 11 interferometric measurements in the period from 1998 through 2006 allowed the determination of the visible ellipse of the system’s motion and the orbital parameters:

- \( P = 2005.49 \pm 0.01 \) yrs,
- \( T = 0 \) yrs,
- \( e = 0.536 \pm 0.007 \),
- \( a = 0.220 \pm 0.002^\prime \),
- \( i = 75.1 \pm 0.4^\circ \),
- \( \Omega = 141.5 \pm 0.3^\circ \),
- \( \omega = 89.5 \pm 0.8^\circ \).

The deviations of the measurements from the computed values are given in Table 3. The first measurement by Hipparcos was not taken into account in the calculations. In addition to the data from Table 1, we have made use of the newest measurement made at the BTA 6 m telescope in 2006. The ellipse of the interferometric orbit is shown in fig. 2. The total mass of HIP 116259 is \( \Sigma M = 1.56 \pm 0.18 \, M_\odot \) (accuracy 12\%) under \( \pi_{\text{HP}} = 30.24 \) mas (Perryman, 1997). As for all Hipparcos new binaries, the parallax error plays a definitive role in the total error of the mass estimate, but not the orbital elements. The spectroscopic orbit of the pair (Latham et al., 2002) has similar characteristics.

**HIP 118212 = GJ 913.** This nearby, \( \pi_{\text{HP}} = 58 \) mas (Perryman, 1997), M-type star was included in the program as a possible binary. It is one of 1561 stars in the Hipparcos Catalog marked with an X flag, which means that only a stochastic solution for their astrometry was found. A part of these stars can be non-single objects, while the other part can be explained by the failure in data reduction. An attempt to improve the parallax of HIP 118212 and to define the character of its motion from the Hipparcos astrometry has recently been made by Goldin and Makarov (Goldin & Makarov, 2006). Using the results of independent observation reductions by two consortia, FAST and NDAC, they calculated a new parallax value for the star, \( \pi_{\text{HP}} = 67 \) mas, and defined the orbit with a period of 885 days.

We first resolved a faint (\( \Delta m = 1.4 \) in the \( I \) band) close (\( \rho = 62 \) mas) companion of HIP 118212 with the BTA 6 m telescope in the 850/75 nm filter. Our measurement does not fit the calculated position on the orbit of Goldin and Makarov (Goldin & Makarov, 2006). The reason for this discrepancy—a new companion or the wrong orbit—can be established in the immediate future using new speckle observations of this presumably fast-moving pair.

## 4. UNRESOLVED OBJECTS

A total of 26 objects were not resolved in the course of the observations. They are listed in Table 3. Due to the marginal weather conditions, some of the binaries with a limiting magnitude difference for speckle interferometry (around 3.5 magnitudes) were not resolved. One example of such a system is HIP 97579, with a remote companion (\( \rho = 687 \) mas, \( \Delta m = 3.46 \)) given in the Hipparcos Catalog. The power spectrum of this pair can be traced up to the limiting frequency of the telescope, but its noisiness could be the reason why the secondary was not detected.

Another unresolved star HIP19270=ADS2984A is a southern component of the wide visual pair. It was observed under poor seeing conditions as a reference source for its northern neighbor ADS 2984 B, which is known as SZ Cam—a distant occultation binary with early-type massive components.

One more unresolved star, HIP 97607 = CHR 89 of B2IV spectral type, appeared in the lists of new binaries after speckle observations with the CFHT 3.6 m telescope in 1985 (McAlister et al., 1987a). Another observation of the star was obtained in the same year by the same authors using the MAYAL 3.8 m telescope at Kitt Peak (McAlister et al., 1987b). However, neither the Hipparcos observations nor the following BTA speckle interferometry confirmed the duplicity. Despite the poor seeing conditions, our observations in 2004 allowed us to study the power spectrum up to the highest spatial frequencies. We do not exclude the possibility that the pair will prove to be a short-period system (\( P \approx 50 \) yr), which is presently unresolved.

The history of speckle observations of HIP 98538 = CHR 118 is similar to the history of the previous star CHR 89. After the only measurement in 1985 (Lu et al., 1987), the companion has never been observed again. Note that the
Table 3. Unresolved stars

| HIP No. | Other catalog No. | Coord. 2000.0 | Epoch 2004.0+ | λ/Δλ, nm | Note |
|---------|------------------|--------------|--------------|-----------|------|
| 916     | GJ 3012          | 00114+5821   | .8210        | 850/75    | X    |
| 1092    | GJ 3015 B        | 00136+8040   | .8210        | 800/110   | X    |
| 1295    |                  |              | .8211        | 800/110   | X, S |
| 1475    | GJ 15 A          | 00184+4401   | .8236        | 850/75    | S    |
| 1860    | GJ 1010 A        | 00235+7711   | .8211        | 800/110   | X, S |
| 3362    | GJ 29.1          | 00428+3533   | .8320        | 800/110   | G    |
| 7765    | ADS 1307 B       | 01399+1516   | .8238        | 545/30    | O    |
| 7981    | HR 493           | 01425+2016   | .8238        | 545/30    | O    |
| 16445   | GJ 143.3         | 03318+1419   | .8214        | 800/110   | X, S |
| 19270   | ADS 2984 A       | 04078+6220   | .8266        | 545/30    | O    |
| 20222   |                  |              | .8243        | 545/30    | O    |
| 31635   | GJ 239           | 06372+1734   | .8217        | 600/20    | S    |
| 36834   | GJ 277.1         | 07345+6256   | .8271        | 800/110   | S    |
| 7479    | HDS 2823         | 19500+3158   | .8232        | 545/30    | S    |
| 7960    | HR 7554          | 19503+0754   | .8250        | 545/30    | S    |
| 98538   | HD 189711        | 20011+0931   | .8250        | 800/110   | S    |
| 101382  | GJ 793.1         | 20329+4154   | .8233        | 600/20    | X, S |
| 102581  | GJ 808.2         | 20502+2923   | .8233        | 600/20    | X, S |
| 103256  | GJ 1259          | 20551+1311   | .8233        | 600/20    | X, S |
| 106886  | ADS 15184 C      | 21390+5729   | .8262        | 545/30    | S    |
| 108467  | GJ 842.2         | 21584+7535   | .8235        | 800/110   | S    |
| 112460  | GJ 873 A         | 22468+4420   | .8319        | 800/110   | S    |
| 114941  | GJ 4323          | 23169+0542   | .8208        | 800/110   | S    |
| 117779  | GJ 910           | 23531+2901   | .8236        | 800/110   | X, S |
| 117795  |                  | 23533+5957   | .8210        | 800/110   | G    |
| 118310  | ADS 17154 A      | 23598+0640   | .8318        | 700/30    | S    |
|         |                  |              |              |           |      |

Table 4. Position parameters and residuals of the measurements of the HIP 109281

| Epoch   | θ, deg | ρ, mas | (O − C)θ, deg | (O − C)ρ, mas | Reference |
|---------|--------|--------|---------------|---------------|-----------|
| 1991.250| 311.0  | 119    | -1.2          | -3            | Perryman, 1997 |
| 1998.774| 32.5   | 68     | 0.3           | 1             | Balega et al., 2002 |
| 1999.741| 356.7  | 86     | 0.1           | -4            | Balega et al., 2002 |
| 1999.821| 354.4  | 93     | -0.1          | 1             | Balega et al., 2004 |
| 1999.885| 352.1  | 90     | -0.6          | -3            | Horch et al., 2002 |
| 2000.764| 333.1  | 97     | 0.1           | -10           | Horch et al., 2002 |
| 2000.872| 331.1  | 108    | 0.2           | -1            | Balega et al., 2006a |
| 2002.736| 301.4  | 131    | 0.2           | 4             | This paper |
| 2002.799| 299.8  | 128    | -0.5          | 1             | This paper |
| 2003.927| 284.8  | 132    | -0.2          | 3             | This paper |
| 2003.927| 284.9  | 132    | -0.1          | 3             | This paper |
| 2004.815| 273.2  | 125    | 0.5           | -1            | This paper |
| 2004.815| 273.1  | 126    | 0.4           | 0             | This paper |
| 2006.690| 239.4  | 96     | 0.0           | 0             | This paper |

Confirmation of the binary nature of the CH star CHR 118 is of great importance for the explanation of the properties of this rare stellar type.

Following the accurate orbit of the spectroscopic and interferometric binary HIP 101382 = HD 195987 = GJ 793.1 with a period of 57.3 days (Torres et al., 2002), the separation between the components in the period of the BTA observations was only 9 mas. That explains our negative result because such a separation is smaller than the diffraction limit of the 6 m aperture. Earlier, Blazit et al. (Blazit et al., 1987) reported the speckle interferometric resolution of...
Table 5. Position parameters and residuals of the measurements of the HIP 116259

| Epoch    | θ, deg | ρ, mas | (O−C)θ, deg | (O−C)ρ, mas | Reference          |
|----------|--------|--------|-------------|-------------|--------------------|
| 1991.25  | 341.0  | 195    | 18.9        | 34          | Perryman, 1997     |
| 1998.775 | 83.0   | 105    | 0.4         | 6           | Balega et al., 2002|
| 2000.617 | 119.6  | 153    | 6.2         | 4           | Horch et al., 2002 |
| 2000.759 | 114.7  | 154    | -0.2        | 1           | Horch et al., 2002 |
| 2000.865 | 115.6  | 157    | -0.4        | 1           | Balega et al., 2006a|
| 2000.873 | 115.6  | 157    | -0.5        | 1           | Balega et al., 2006a|
| 2001.761 | 123.5  | 177    | -0.3        | 0           | Balega et al., 2006a|
| 2001.761 | 123.8  | 174    | 0.0         | -3          | Balega et al., 2006a|
| 2002.796 | 130.9  | 185    | -0.3        | -3          | This paper         |
| 2004.824 | 152.1  | 99     | 0.2         | 0           | This paper         |
| 2006.690 | 319.3  | 146    | -0.1        | 1           | This paper         |
| 2006.946 | 321.9  | 161    | -0.1        | 0           | This paper         |

the system with the CFHT 3.6 m telescope in 1985: θ=170°, ρ=30 mas. The ephemeris separation value in the period of their observation was also equal to 9 mas; therefore, the binary could not be resolved at CFHT, which has a diffraction limit of ≈40 mas.

In the spectroscopic binary system HIP 103256 = GJ 1259, the companion’s mass is 7 times lower than the mass of the main K3V star (Halbwacks et al., 2003). The luminosities of a K3V star and a late red dwarf differ in the visible by 7–8 magnitudes, ruling out the possibility for speckle resolution of the components.

The system ADS 15184 C,D (HIP 106886) is a member of the OB star complex. The stars were included in the program as reference sources for the triple star ADS 15184 A = MIU 2, which includes both a spectroscopic pair and a remote O companion (Burkholder et al., 1997). Mason et al. (Mason et al., 1998) observed the C and D components of ADS 15184 earlier and could not detect a sign of their multiplicity. It should also be taken into account that our observations were carried out under poor seeing conditions.

The nearby (π_{HIP}=39 mas) K5V star HIP 118310 = ADS 17154 Aa = Bag 31 was first resolved with the BTA 6 m telescope in 2001 with ρ ≈0.2′′. Three years later, the secondary was not detected despite the fact that the power spectrum was accumulated to the limiting frequencies. We conclude from this that the pair can show a fast orbital motion with a period of ≈10 years.

In the last column of Table 3 we present flags for the Hipparcos Catalog “problem” stars with the following astrometric solutions: G, motion with acceleration, X, stochastic solution for the photocenter motion, S, possible non-single system. Flag O stands for HIP 7981 with the computed Hipparcos astrometric orbit. Following this orbit, the binary is too close to be resolved with the 6 m telescope. As it follows from our earlier observations, up to 30–35% of the Hipparcos “problem” stars could be resolved using the speckle interferometry at the BTA 6 m telescope (Balega et al., 2006a). In the 2004 observations, only one out of six new stars in this category was resolved for the first time (HIP 118212). Other Hipparcos “problem” stars (HIP 916, 1092, 1475, 1860, 3362, 7765, 7981, 16445, 31635, 36834, 108467, 112460, 117795) still remain unresolved.

5. CONCLUSION

Speckle interferometric observations of 110 binary and multiple stars were taken in 2004 October at the BTA 6 m telescope with the diffraction resolution of the aperture: 19 mas in the 545/30 nm filter, 21 mas in the 600/30 nm filter, 28 mas in the 800/110 nm filter, and 29 mas in the 850/75 nm filter. Most of the objects in the program are nearby late-type dwarfs. About half of them are new pairs discovered by the Hipparcos astrometric satellite.

197 measurements of position angles and distances between the components of multiple systems have been collected in Tables 1 and 2. The errors of the measurements range from 0.3° to 3.1° for the position angle and from 2 to 8 mas for the angular separation. The closest among the resolved pairs is θ Ori C with a separation between the components of 23 mas, corresponding to 83% of the limiting resolution. The widest observed pair is ADS 14575 (ρ=1.6″), which is a standard star for the binary star speckle interferometry. In a separate table, we give a list of 26 stars that remained unresolved in 2004.

In this paper we presented 154 measurements of the brightness difference between the components of binary and multiple stars. In the last few years, this has become the standard procedure in stellar speckle interferometry and is significant for deriving the physical properties of studied stars.
The symbiotic system CH Cyg and the pair of red dwarfs HIP 118212 were resolved for the first time. The observations of the binary system CH Cyg are of particular importance because up to now, there has been no satisfactory model for this nearby symbiotic star, and the nature of its activity remains unclear. Nor has it been determined whether the carbon-oxygen white dwarf in the system is able to accumulate mass due to accretion from its cool companion until it approaches the Chandrasekhar limit and becomes a supernova SN Ia progenitor.

Using BTA speckle interferometry, we obtained first orbits for two binaries: the CN giant system HD 210211 = HIP 109281 with a period of 10.7 yrs, and the G2V-K4 V pair GJ 9830= HIP 116259 with a period of 15.7 yrs. Their orbital elements and (O–C) deviations from the predicted positions are presented in the paper.

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