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# Multicolour CCD measurements of visual double and multiple stars. III⋆,⋆⋆,⋆⋆⋆

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**ABSTRACT**

*Context.* Recent CCD observations were performed in the period 1998−2004 for a large sample of visual double and multiple stars selected from the Hipparcos Catalogue and/or from the Gliese Catalogue of Nearby Stars.
*Aims.* Accurate astrometric and photometric data allowing us to characterise the individual components are provided. These data are compared to Hipparcos data or to data from an older epoch to assess the nature of the observed systems.
*Methods.* We simultaneously apply a Moffat-Lorentz profile with a similar shape to all detected components and adjust the profile parameters from which we obtain the relative astrometric position (epoch, position angle, angular separation) as well as differential multi-colour photometry (filters $(B)VRI$).
*Results.* We thus acquired recent data for 71 visual systems of which 6 are orbital binaries, 27 are nearby, and 30 are multiple systems. In three of these cases, the systems remained unresolved. 23 new components were detected and measured. Two new visual double stars of intermediate separation were also found. The estimated accuracies in relative position are 0.04° and 0.01″ respectively, while those in differential photometry are of the order of 0.01−0.02 mag in general.
*Conclusions.* The nature of the association of 55 systems is evaluated. New basic binary properties are derived for 20 bound systems. Component colours and masses are provided for two orbital binaries.

**Key words.** stars: binaries: visual – techniques: photometric – stars: fundamental parameters

## 1. Introduction

The context of the present work is the field of visual binaries (double) and multiple stars. We report on the acquisition of recent astrometric and multi-passband photometric data following the procedure described in our previous work (Lampens & Strigachev 2001, Paper I; Strigachev & Lampens 2004, Paper II). During the years 1998−2004, we performed regular CCD observations of a sample of visual double and multiple stars selected from the Gliese Catalogue of Nearby Stars and/or from the Hipparcos Catalogue (ESA 1997) at the National Observatory of Rozhen (NAO) and at the Astronomical Observatory of Belogradchik (AOB), both situated in Bulgaria. Our goal is to improve the knowledge of the distributions of the true separations, relative motions, (total and individual) masses, luminosity ratios, and temperature differences of the main-sequence visual binaries situated in the near Solar neighbourhood. An accurate determination of the distributions of the binary properties is needed to provide observational constraints to the various existing scenarios of binary star formation, and offers a direct calibration tool for basic stellar properties. As the field main-sequence binaries serve as a reference for various binary populations in different environments (e.g., in clusters, in metal-poor or star-forming regions), it remains worthwhile to improve their statistics and the data obtained in the past (at a time when visual double stars were still "fashionable"), more particularly also for the wide binaries that carry the largest angular momenta, but that are also the ones most prone to dynamical disruption (Mathieu 2001). For these purposes, monitoring of the (changing) astrometric parameters providing the fundamental binary data as well as precise measuring of the individual magnitudes and colour indices of the components is absolutely needed. Accurate photometric differences allow the characterisation of the evolutionary stage of the components since basic properties such as luminosity/mass ratios as well as temperature differences may be derived.

The paper is structured in the following way: firstly, we describe the sample (Sect. 2), next we report on the observations, the reduction method and the astrometric calibration (Sect. 3). In Sect. 4 we present new astrometric and photometric measurements including a discussion of the errors. We compare our measurements to Hipparcos or older data, derive the properties of individual systems, and discuss some unresolved systems in Sect. 5. A short summary of the observational results can be found in Sect. 6.

⋆ Based on observations collected at the National Astronomical Observatory, Rozhen, and the Astronomical Observatory, Belogradchik, both operated by the Institute of Astronomy, Bulgarian Academy of Sciences. Also based on data obtained by the Hipparcos astrometry satellite.
⋆⋆ Appendix A is only available in electronic form at http://www.aanda.org
⋆⋆⋆ Tables 4–6 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/464/641

**Table 1.** Adopted limits of target selection as a function of angular separation.

| Limit | $\rho \leq 1.5''$ | $\rho \leq 5''$ | $\rho \leq 12''$ | $\rho > 12''$ |
|---|---|---|---|---|
| $\Delta\rho/\rho$ (%) | 55 | 20 | 8 | 10 |
| Absolute | 0.8″ | 1.0″ | 1.0″ | >1.5″ |

## 2. Description of the sample

We present high-accuracy relative astrometry and *(B)VRI* differential photometric data for a large sample of visual double and multiple stars pertaining to the Hipparcos Catalogue (ESA 1997). Complementary ground-based, multi-colour observations of the components of double stars observed during the Hipparcos mission are valuable because they provide accurate colour differences and independent monitoring of the relative position with the same high accuracy, provided that the angular separation is large enough. At the start of this project, a careful comparison between the CCDM catalogue (Dommanget & Nys 2002) on the one hand and the Hipparcos relative data of visual double stars (i.e., the Hipparcos Double and Multiple Systems Annex or Vol. 10, mainly Component Solutions (DMSA, Part C)) on the other hand showed that, in almost 10% of the ≈9000 cases explored, a discrepancy was noted. This discrepancy can refer to the relative astrometry being discordant (with limits for target selection as a function of angular separation as shown in Table 1) found in 3.2% of the cases or to the relative photometry showing an excess of 1.2 mag at least in $\Delta m$ (independent of the used filter) found in 6.4% of the cases. This may seem a significant fraction whereas a comparison between Hipparcos and a sample of speckle binaries showed good agreement at the mas level (Mignard et al. 1995). When the relative astrometry is obviously conflicting with the previous (generally much older) ground-based data for systems with larger angular separations, we can expect to be able to validate the space results and to show evidence of relative motion between the components, or a new component might have been detected by the satellite, or the space results maybe refuted, permitting us to correct the "ambiguous" solution proposed in the Hipparcos Catalogue (typically at an angular separation larger than 10″). When a large difference in differential magnitude is detected, one may also expect various reasons: a different signal in the considered passband, flux variability, a wrong component identification, a new component detection, or an "ambiguous" Hipparcos solution. Further criteria adopted to select the programme double stars were:

– accessibility from the Northern hemisphere ($\delta > 0°$);
– they should be of "intermediate" angular separation ($1.5'' \leq \rho < 15''$).

The initial target list consisted of 245 candidate visual double or multiple systems listed in the Hipparcos Catalogue. Due to their apparent brightness, it appeared that several among these systems were also listed in the Catalogue of Nearby Stars (GJ, Gliese & Jahreiss 1991).

From 2000 onward, we focused our attention specifically on those visual double and multiple stars of our target list that are in the Catalogue of Nearby Stars (GJ, Gliese & Jahreiss 1991) and/or have Hipparcos parallaxes larger than 0.04″. As before, we chose systems of "intermediate" angular separation fainter than apparent visual magnitude 7 and for which CCD observations can provide both accurate and complementary data on each component (cf. Paper I). To complete our sample of nearby systems, we also added a small number of faint systems that are not included in the Hipparcos Catalogue (because they were beyond the Hipparcos magnitude limit; they will accordingly be designated by their Gliese number). The absolute parallax measurements, obtained in space of the nearby systems from the sample, are generally very accurate. In a few cases, however, the ground-based parallaxes from "The General Catalogue of Trigonometric Stellar Parallaxes" (van Altena et al. 1995, vALH) attain a higher accuracy and supersede the Hipparcos parallax.

**Table 2.** Telescopes and instrumentation.

| Site | NAO Rozhen | AO Belogradchik |
|---|---|---|
| Telescope | 2-m Ritchy-Chrétien | 60-cm Cassegrain |
| CCD type | Photometrics AT200 | ST8 |
| Chip | Site SI003AB UV-AR | KAF 1600 |
| Chip size | 1024 × 1024 pixels | 765 × 510 pixels[1] |
| Pixel size | 24 × 24 $\mu$m | 18 × 18 $\mu$m[1] |
| Scale | 0.31″/pixel | 0.49″/pixel[1] |
| Field | 5.3′ × 5.3′ | 6.2′ × 4.2′ |
| Gain | 4.93 e⁻/ADU | 2.3 e⁻/ADU |
| RON | 1.03 ADU/rms | 10 ADU/rms |

[1] With a binning factor of 2 × 2.

## 3. Observations and data reduction

### 3.1. Instrumentation and limitations

The observations were performed at two observatories – with the 2-m telescope of NAO (Rozhen, Bulgaria) and with the 0.6-m telescope of AOB (Belogradchik, Bulgaria). The main characteristics of the telescopes and their cameras are listed in Table 2. The telescope and the camera used at AOB are described in great detail in Bachev et al. (1999). During this period, out of a total of 25 allocated nights, some 35% of the available time was effectively used.

The CCD frames were taken from October 1998 to November 2004 through standard Johnson *V* and Cousins *R*, *I* filters. At a later stage at NAO, we also used the Johnson filter *B*. During the observations the exposure times were adjusted to get the highest possible counts for the primary (brighter) component; exposure times were usually several seconds long. On each night, a set of biases was taken every few hours. Flat-fields were obtained during evening and/or morning twilights: a set of 3 to 6 flats per filter was taken every night. Typical seeing values ranged from 1.5 to 3″.

### 3.2. The reduction method

All the primary reduction steps were performed using ESO-MIDAS standard routines. The frames were processed for bias and flat-field corrections. They include: subtraction of the residual bias pattern using a median master zero exposure frame and flat-fielding using a median master flat-field frame.

Next, we computed the angular separations (in pixel units), the position angles, and the magnitude differences in the various filters for the components of the double stars. For this we used a two-dimensional Moffat-Lorentz profile (Moffat 1982) fitting method. The code was developed within the ESO-MIDAS environment (Cuypers 1997) and used in previous work (Lampens et al. 2001; Paper I; Paper II).

**Table 3.** Astrometric calibration.

| Observatory[1] | Astrometric standard field | Date | Scale (″/px) | $\sigma$(Scale) (″/px) | Orient. (°) | $\sigma$(Orient.) (°) | N_Stars | Source of coordinates |
|---|---|---|---|---|---|---|---|---|
| NAO | M 15 | 1998 | 0.311 | 0.002 | –1.68 | 0.03 | 13 | Guide Star Catalogue (V7) |
| NAO | NGC 1647 | 2000 | 0.310 | 0.001 | –1.5 | 0.1 | 3[2] | Geffert et al. (1992) |
| NAO | M 15 | 2001 | 0.310 | 0.001 | –2.04 | 0.02 | 8 | Le Campion et al. (1996) |
| NAO | M 67 | 2002 | 0.310 | 0.001 | 0.716 | 0.003 | 9 | Tycho Catalogue (ESA 1997) |
| NAO | M 67 | 2004 | 0.314 | 0.001 | 1.42 | 0.02 | 15+[3] | Girard et al. (1989) |
| AOB | NGC 1647 | 1998 | 0.493 | 0.01 | 2.29 | 0.1 | 10[4] | Geffert et al. (1992) |
| AOB | M 15 | 1999 | 0.495 | 0.001 | 0.4 | 0.1 | 5 | Guide Star Catalogue (V7) |
| AOB | M 16 | 2000 | 0.493 | 0.001 | –1.62 | 0.04 | 9 | Hillenbrand et al. (1993) |

[1] NAO Rozhen: 2-m telescope; – AO Belogradchik: 0.6-m telescope; [2] Field I; – [3] Fields I and III; – [4] Fields I and IV.

### 3.3. The astrometric calibration

To convert the instrumental angular separations and position angles into absolute values we applied the astrometric corrections as computed from stars observed in various standard astrometric fields (see Table 3). We measured the $(x, y)$ positions and computed a multi-linear regression fit between the $(x, y)$ positions and the catalogued $(\alpha, \delta)$ values of the standard stars. Typically, we used 8–9 or more stars (cf. Col. 8 in Table 3) with reference coordinates in each field. On one occasion, only 3 stars were used. To compensate for this low number of reference stars (particularly in NGC 1647), we computed the mean calibration obtained from two such fields whenever possible. We then determined the pixel scale and the orientation of the CCD chips (measured from North towards East). For this computation we made use of the software package Mira AP[1] as well as of self-made codes. Both gave equivalent results for the same field. The adopted corrections are listed in Table 3. In Col. 9 we mention the source of the coordinates of the standard fields. The relative astrometric data were corrected using the appropriate values. The computed scale values of Table 3 are not exactly the same as the nominal instrumental specifications (Sect. 3.1).

## 4. CCD astrometry and photometry

### 4.1. Astrometric measurements

The astrometric data are listed in Table 4. The first column mentions the Hipparcos identification number, followed by the component identification, the epoch (Bessel year), the number of frames, the angular separation ($\rho$) and the position angle ($\theta$) measured from North to East, with the respective standard errors $\sigma(\rho)$ and $\sigma(\theta)$. The values of $\rho$ and $\theta$ are the means of several frames measured in different filters. Typically, as many as 20–30 frames were obtained for each target, all filters included.

The standard errors of the mean values are quoted. These values are systematically better in the case of the NAO measurements: the mean uncertainties are 0.01″ in angular separation and 0.04° in position angle. Such errors are typical for this range of angular separation (i.e., "intermediate", Lampens et al. 2001). The resolution is also higher, as shown by the measurement of HIP 97237, with the smallest angular separation measured ($\rho$ = 1.4″). At AOB, the mean uncertainties are somewhat larger, i.e., 0.04″ in angular separation and 0.26° in position angle. Figure 1 illustrates the uncertainty in $\rho$ as a function of angular separation and of differential $V$ magnitude between the components.

[1] The software Mira AP is produced by Axiom Research Inc., http://www.axres.com/.

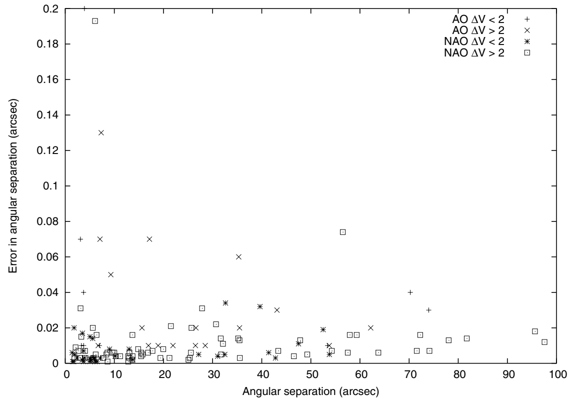


**Fig. 1.** Astrometric error vs. angular separation (in arcsec).

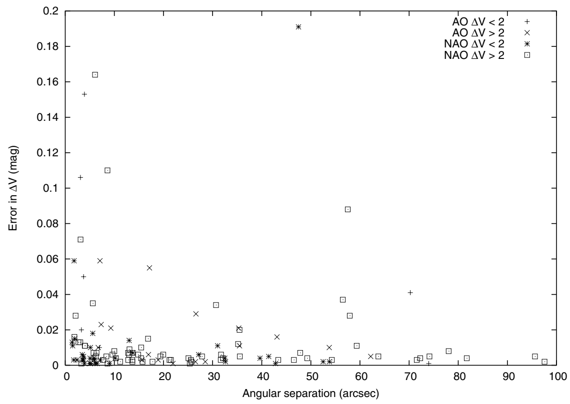


**Fig. 2.** Photometric error vs. angular separation (in arcsec).

### 4.2. Photometric data

In Table 5 we list the photometric magnitude and the colour differences in the following order: the Hipparcos number (Col. 1), the component identification (Col. 2), the heliocentric Julian Date (Col. 3), the differential $V$ magnitude ($\Delta V$) (Col. 4), and the colour differences ($\Delta B - \Delta V$), ($\Delta V - \Delta R$), and ($\Delta V - \Delta I$) (Cols. 5, 7, 9, and 11), as well as the respective standard errors of the differences (Cols. 6, 8, 10, and 12). As before, we consider that these values reflect the true colour differences between the components (e.g., $\Delta(B-V)$). The standard errors of the mean values are quoted. The mean error of the differential $V$ magnitude is 0.01 mag for the NAO observations while it is 0.03 mag for the AOB observations. Again, such mean internal errors are conform with expected values (Lampens et al. 2001). Figure 2 illustrates the uncertainty in $\Delta V$ as a function of angular separation and of the difference in $V$ magnitude between the components.

**Table 7.** Orbital systems and comparison with the ephemeris based on the best-fitting orbit(s).

| Identifier | $\rho_{obs}$ | $\theta_{obs}$ | $\rho_{eph}$ | $\theta_{eph}$ | $\delta\rho$ | $\delta\theta$ | $\Delta$Pos | Source |
|---|---|---|---|---|---|---|---|---|
| HIP 473 | 6.079 | 178.49 | 6.068 | 182.61 | 0.011 | –4.120 | 0.437 | Kiyaeva et al. (2001) |
| HIP 67422 | 3.30 | 170.70 | 3.320 | 173.48 | –0.020 | –2.780 | 0.162 | Heintz (1988) |
| HIP 72659 | 6.72 | 314.20 | 6.636 | 317.28 | 0.084 | –3.080 | 0.369 | Söderhjelm (1999) |
| HIP 79607 | 6.96 | 232.80 | 6.955 | 236.13 | 0.005 | –3.330 | 0.404 | Ruymaekers (1999) |
| HIP 88601 | 3.73 | 145.60 | 3.780 | 147.24 | –0.050 | –1.640 | 0.119 | Ruymaekers (1999) |
| HIP 97237 | 1.418 | 46.98 | 0.940 | 82.54 | 0.478 | –35.560 | 0.852 | Heintz (1990) |
| HIP 97237 | 1.418 | 46.98 | 1.521 | 47.44 | –0.103 | –0.460 | 0.104 | Söderhjelm (1999) |

**Table 8.** Basic binary properties: component colours and masses.

| Identifier | $(B-V)_{AB}$ | $(B-V)_A$ | $(B-V)_B$ | $\Delta$BC | $\Delta M_{Bol}$ | $\beta$ | $M_{A+B}$ ($M_\odot$) | $\sigma(M_{A+B})$ ($M_\odot$) | $M_A$ ($M_\odot$) | $M_B$ ($M_\odot$) |
|---|---|---|---|---|---|---|---|---|---|---|
| HIP 473[1] | 1.443 | 1.444 | 1.442 | 0.004 | 0.064 | 0.496 | 1.496 | 0.27 | 0.75 | 0.74 |
| HIP 1860 | 1.450 | 1.453 | 1.402 | 0.109 | 2.973 | 0.328 | – | – | – | – |
| HIP 15844 | 1.500 | 1.512 | 1.463 | 0.130 | 1.407 | 0.416 | – | – | – | – |
| HIP 17666 | 0.799 | 0.751 | 0.887 | –0.113 | 0.474 | 0.471 | – | – | – | – |
| HIP 29316 | 1.450 | 1.446 | 1.469 | –0.053 | 1.575 | 0.406 | – | – | – | – |
| HIP 43422 | 1.355 | 1.216 | 1.521 | –0.578 | –0.536 | 0.532 | – | – | – | – |
| HIP 44295 | 1.285 | 1.191 | 1.395 | –0.308 | –0.244 | 0.515 | – | – | – | – |
| HIP 92836 | 1.370 | 1.367 | 1.429 | –0.118 | 3.186 | 0.317 | – | – | – | – |
| HIP 97237 | 1.720 | 1.739 | 1.709 | –0.612 | –0.003 | 0.500 | 0.463 | 0.086 | 0.23 | 0.23 |
| HIP 110640[1] | 1.190 | 1.162 | 1.480 | –0.530 | 1.848 | 0.390 | – | – | – | – |
| HD 23713 | 0.544 | 0.156 | 1.346 | –0.849 | –0.638 | 0.538 | – | – | – | – |

[1] Cf. also Paper II.

## 5. The nature of the association of individual systems and some unresolved systems

In Table 6 we show the difference in relative position, ΔPos, (Col. 9) between the new values and those from the Hipparcos Catalogue (for mean epoch 1991.25). When no Hipparcos data were available, we used the (sometimes much) older data from the CCDM (Dommanget & Nys 2002). Also listed are the catalogue's epoch (Col. 4), the published position angle (Col. 5) and angular separation (Col. 6), the computed differences in $\rho$ (Col. 7), and $\theta$ (Col. 8). Lastly, we briefly comment on the nature of the association of the system using a number of codes ("S" = stable; "L" = showing a linear relative motion (optical system); "M" = showing (orbital) motion; and "O" = with known orbital motion). Code "L" is used when the difference in relative positions is compatible with the (measured or estimated) relative proper motion of the components considered, while code "M" is assigned when this is not the case. The derived properties for some of the orbital binaries in the sample under study have already been published (Paper II). Therefore, we will not include these binaries in the discussion, unless they are part of a complex (e.g., multiple) system. However, they are included in Table 7, where a comparison is made with the ephemeris computation based on previously known orbits (Mason et al. 2001).

The comments addressing specific systems of Tables 6 and 7, which for various reasons do not form stable configurations (i.e., are not fixed systems) can be found in the Appendix. In Tables 8 and 9, we list newly derived binary properties for 20 bound systems of Table 6. We provide the system's $(B-V)$ colour index (Col. 2), the component colours (Cols. 3 and 4), the bolometric correction difference (Col. 5), the bolometric magnitude difference (Col. 6), and the subsequently derived fractional mass, $\beta$, (Col. 7) (Table 8). In Table 9, we provide (lower limits of) the linear separations based on the observed angular separations (generally corresponding to larger semi-major axes) by making use of the most precise parallaxes known to-date (a note in Col. 13 indicates the use of a ground-based trigonometric parallax).

In seven cases, the companion (component B) was not detected and thus not measured. This was the case for the following systems: HIP 8414 (1991: $\rho = 1.7''$), HIP 21765 (1960: $\rho = 2''$), HIP 30920, HIP 101150, HIP 105747 (1991: $\rho = 0.1''$), GJ 1047 AB (1966: $\rho = 1''$), and GJ 1103 AB. In six cases (not GJ 1103), the angular separation previously measured was (well) below 2″. We also did not resolve the binary GJ 1103 AB, which was measured with an angular separation of about 3″ in 1960. On the other hand, we know that the adopted lower limit of 1.5″ in angular separation can be reached under good circumstances (depending, e.g., on seeing and on the observed magnitude difference, e.g., HIP 97237 and HIP 113437). We therefore claim that the most probable reason for non-detection in these systems is the fact that the binaries presently have an angular separation equal to or below 1.7″ (1.5″ for $\Delta m < 1$ mag). They were presently unresolved by the adopted CCD technique. In the case of HIP 30920, component B is actually situated at an angular separation of 1.3″ (Mason et al. 2001), whereas the Hipparcos angular separation of HIP 101150 was only 0.8″ (epoch 1991.25). HIP 12781 and HIP 28368 are two newly discovered doubles according to the Hipparcos Catalogue (ESA 1997) for which we report no detection of an additional component with a separation above 1.7″ (1.5″ for $\Delta m < 1$ mag).

## 6. Conclusions

We provided high-accuracy astrometric and photometric measurements for 71 visual systems, of which 27 are nearby (with parallax less than 30 pc) and 30 are multiple systems. In three additional cases, the binary systems remained unresolved. From a comparison with the relative positions from the Hipparcos Catalogue (for mean epoch 1991.25) or, when no Hipparcos data were available, with the data from the CCDM Catalogue, we

**Table 9.** Basic binary properties: (lower) linear separations for 20 bound systems.

| Identifier | Cp | Epoch (Bessel yr) | N_ima | $\rho$ ($''$) | $\sigma_\rho$ (mas) | $\theta$ ($^\circ$) | $\sigma_\theta$ ($^\circ$) | $\pi$ (mas) | $\sigma_\pi$ (mas) | $A_{\rm low}$ (AU) | $\sigma_{\rm A}$ (AU) | Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HIP 473 | B | 2001.8583 | 24 | 6.079 | 1 | 178.49 | 0.01 | 85.10 | 2.74 | 71 | 2 | |
| HIP 1860 | B | 2001.8611 | 58 | 11.178 | 4 | 58.13 | 0.03 | 50.71 | 2.72 | 220 | 12 | vALH |
| HIP 4258 | B | 2001.8584 | 24 | 6.488 | 1 | 66.52 | 0.01 | 8.59 | 2.24 | 755 | 202 | vALH |
| HIP 9275 | B | 2000.8238 | 40 | 3.926 | 3 | 54.57 | 0.07 | 33.53 | 5.29 | 117 | 18 | |
| HIP 15844 | B | 2000.8213 | 23 | 2.397 | 3 | 340.90 | 0.05 | 50.54 | 4.66 | 47 | 4 | |
| HIP 17666 | B | 2000.8267 | 48 | 7.139 | 3 | 51.81 | 0.02 | 40.83 | 2.24 | 175 | 10 | |
| HIP 21088 | B | 2000.8213 | 15 | 9.022 | 8 | 61.81 | 0.08 | 180.60 | 0.80 | 49.9 | 0.3 | vALH |
| HIP 22715 | B | 2000.8324 | 5 | 3.980 | 3 | 216.32 | 0.03 | 37.09 | 1.37 | 107 | 4 | |
| HIP 29316 | B | 2000.8216 | 20 | 1.803 | 20 | 27.04 | 0.50 | 97.90 | 3.90 | 18 | 1 | vALH |
| HIP 39896* | B | 2004.8843 | 15 | 13.750 | 2 | 240.32 | 0.02 | 48.26 | 3.16 | 285 | 19 | |
| HIP 41824 | B | 2000.8353 | 18 | 10.149 | 4 | 344.76 | 0.01 | 78.05 | 5.69 | 130 | 10 | |
| HIP 43422 | B | 2002.9106 | 12 | 1.717 | 1 | 153.07 | 0.04 | 31.24 | 19.30 | 55 | 34 | |
| HIP 44295* | B | 2004.8845 | 15 | 5.100 | 3 | 180.80 | 0.01 | 54.57 | 3.21 | 93 | 5 | |
| HIP 92836 | B | 2001.8637 | 48 | 4.021 | 7 | 32.92 | 0.02 | 50.30 | 2.70 | 80 | 4 | |
| HIP 97237 | B | 2000.8342 | 19 | 1.418 | 6 | 46.98 | 0.21 | 94.70 | 4.40 | 15 | 1 | vALH |
| HIP 110640 | B | 2001.8582 | 55 | 2.103 | 9 | 220.94 | 0.27 | 46.74 | 1.66 | 45 | 2 | |
| HIP 113437 | B | 2001.8610 | 24 | 1.515 | 1 | 252.96 | 0.09 | 8.19 | 1.52 | 185 | 34 | |
| HD 23713 | B | 2000.8296 | 15 | 1.935 | 5 | 126.96 | 0.11 | 45.00 | 15.00 | 43 | 14 | vALH |
| GJ 1047 | C | 2000.8321 | 24 | 31.025 | 4 | 233.25 | 0.04 | 46.20 | 3.60 | 672 | 52 | vALH |
| GJ 1245 | B | 2000.8344 | 20 | 7.035 | 3 | 79.63 | 0.02 | 220.20 | 1.00 | 32.0 | 0.2 | vALH |

[*] This flag denotes another epoch for the same target (cf. Table 4).

evaluated the physical status of 55 systems. To summarize, we found that:

- 8 systems show a linear relative motion (optical);
- 17 systems are true binaries showing motion;
- 22 systems show a fixed configuration;
- 5 systems probably show a fixed configuration;
- 3 binaries have a published orbit.

Comparison of the new measurements and the ephemerides computed with the orbits found in the literature shows a reasonably good agreement in the case of three binaries (HIP 67422, HIP 88601, and HIP 97237), but too large residuals in the other cases (HIP 473, HIP 72659, and HIP 79607) (cf. Table 7). The long-term monitoring of these orbital pairs should be pursued with an adequate angular resolution. Two new visual double stars of intermediate separation were also discovered, one of which (HD 218587) was already reported elsewhere (Strigachev et al. 2001). 23 new components of known systems were measured and basic binary properties were newly determined for 20 bound systems. In the case of two orbital binaries, we derived a full set of fundamental parameters including new component colours and corresponding component masses.

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# Online Material

## Appendix A: List of comments addressing specific systems of Tables 6 and 7, which for various reasons do not show a fixed binary configuration

*HIP 473*: GJ 4 AB is a nearby orbital pair ($\pi_{\rm Hip}$ = 85.10 ± 2.74 mas) in a multiple system showing a high common proper motion (comp A: total proper motion (pm) of 0.891″/yr in the direction 100°, comp B: total pm of 0.853″/yr in the direction 101°), also for example HIP 428 (comp F: total pm of 0.883″/yr in the direction 100°) (ESA 1997). The relative position of component E is consistent with a change in the position of GJ 4 AB over a period of 77 years. The comparison with the ephemeris of Kiyaeva et al. (2001) is less concordant than previously (in Paper II we already stated that this orbit may not be definitive). The observed change of rate of the position angle is opposite to the expected one. The system was recently also measured by Pavlovic et al. (2005) who have found good agreement with the proposed ephemeris, but have less accuracy than our data. For this reason also, we thoroughly checked the determination of the zero point of the orientation angle.

*HIP 1397*: shows a significant proper motion, definitely L-type. This is confirmed by the Hipparcos difference in proper motion of the order of 0.1″/yr between the "components" in the direction 10°, which is fully compatible with the observed change in relative position of almost 1″ (i.e., ΔPos = 0.942″) over slightly more than 10 years ($\pi_{\rm Hip}$ = 11.30 ± 1.39 mas, ESA 1997).

*HIP 1860*: GJ 1010 AB, a nearby system with a high proper motion, possibly M-type (total pm of 0.800″/yr in the direction 273° and $\pi_{\rm tr}$ = 62.8 ± 4.0, van Altena et al. 1995). There is no double-star solution mentioned in the Hipparcos Catalogue (since it is listed in DMSA/X, Part X which contains the stochastic solutions for objects for which no single nor double star solution could be found in reasonable agreement with the standard errors of the Hipparcos observations) (ESA 1997). It forms a common proper-motion binary listed in Gould & Chaname (2004) (=NLTT 1186 and 1189).

*HIP 3589*: shows a significant proper motion, most probably L-type. This is confirmed by the Hipparcos difference in proper motion of the order of 0.1″/yr between the "components" ($\pi_{\rm Hip}$ = 20.56 ± 1.69 mas).

*HIP 4258*: GJ 1023 AB shows a significant proper motion (total pm of 0.100″/yr in the direction 250°, ESA 1997), most probably M-type. It has $\pi_{\rm tr}$ = 53.0 ± 15.9 mas (van Altena et al. 1995), whereas $\pi_{\rm Hip}$ = 8.59 ± 2.24 mas.

*HIP 7495*: the new measurement confirms the Hipparcos "alternative" solution rather well (ESA 1997).

*HIP 9275*: GJ 1041 AB has a high proper motion (total pm of 0.260″/yr in the direction 84°, ESA 1997), probably M-type ($\pi_{\rm Hip}$ = 33.53 ± 5.29 mas). There is no differential proper motion known.

*HIP 9867*: GJ 84.2 AB, also BD +44°423 (not BD +44°422), is a high proper motion (pm of 0.510″/yr in the direction 148°, van Altena et al. 1995) and a possible EA variable star (=V 374 And) ($\pi_{\rm tr}$ = 53.5 ± 5.2 mas). Component *B* is in the field but was at first not identified (this component is mentioned in the CCDM but not in the NLTT catalogue). GJ 84.2 AB (Wor 1) is evidently an optical pair. Though they are background stars, two "components" (B?, E′) were also measured. We think that background star B? probably corresponds to component B (located at (307°, 4.4″) in 1959). Note that another recent position of component B? has also been attributed to component B (Mason et al. 2001). The relative position is concordant with a change in the position of component A over a period of 42 years. The relative position of component C is also concordant. The Hipparcos stochastic solution was rejected because it had a "cosmic error" greater than 100 mas (ESA 1997).

*Unresolved system HIP 12781*: GJ 109 (=LHS 1439), also the flare star VX Ari, has a huge proper motion (total pm of 0.924″/yr in the direction 114° (van Altena et al. 1995) and $\pi_{\rm Hip}$ = 127.3±4.2 mas). It is included in the Double and Multiple Systems Annex with a variable component (DMSA/V, Part V which contains the VIM solutions for objects where the duplicity has been inferred by a photocentric motion caused by the variability of one of the components (i.e., Variability Induced Movers)) (ESA 1997). We report no detection of an additional component with a separation above 1.7″ (1.5″ for $\Delta m < 1$ mag).

*HIP 15844*: GJ 140 AB has a high proper motion (pm of 0.253″/yr in the direction 121°, ESA 1997), the binary motion is confirmed ($\pi_{\rm Hip}$ = 50.54 ± 4.66 mas) (Paper II). Component C was not in the field (=NLTT 10808 at (118.2°, 99.5″)), but forms a common proper-motion pair with component A (Gould & Chaname 2004).

*HIP 17102*: Wo 9119 AB. This measurement does not agree with the Hipparcos nor with the Hipparcos "alternative" solution. The observation is nevertheless consistent with it as the difference with the Hipparcos solution is almost exactly 1 gridstep (equal to 1.2″) ($\pi_{\rm Hip}$ = 20.03 ± 2.14 mas).

*HIP 17666*: GJ 1064 AB, also a variable star with a huge proper motion (comp A: pm of 1.377″/yr in the direction 154°, comp B: pm of 1.384″/yr in the direction 155°, ESA 1997), shows a binary motion ($\pi_{\rm Hip}$ = 40.83 ± 2.24 mas). There is an important difference in position angle between the two observations (this work; Paper II). A note in the Hipparcos Catalogue reports "Possibly E type. The double-star analysis indicates that it is probably the fainter (B) component which is variable".

*HIP 21088*: GJ 169.1 AB has a huge proper motion (pm of 2.383″/yr in the direction 145°; $\pi_{\rm tr}$ = 180.6 ± 0.8 mas, van Altena et al. 1995). Both measurements (this work; Paper II) agree very well. Compared to the Hipparcos double-star solution, the system shows a distinct orbital motion (M-type) in agreement with older data. It also has an "alternative" Hipparcos solution that is less consistent. Since ΔPos is, however, close to 1 gridstep, the Hipparcos double-star solution should be treated with caution. Both components (=NLTT 13373 and 13375) form a common proper-motion binary (Luyten 1979).

*HIP 22715*: GJ 2035 AB has a high proper motion (pm of 0.197″/yr in the direction 131°, ESA 1997). The Hipparcos Catalogue gives no double-star solution ($\pi_{\rm Hip}$ = 37.09 ± 1.37 mas). The proper motion applied over a period of 100 years does not explain the relatively small value of ΔPos of 1.4″ (we would expect a 10-fold increase if it were an optical binary and the change in relative position was entirely caused by the difference in proper motion between the companions). Orbital motion is possibly detected with a rate in position angle of about 0.2°/yr.

*Unresolved system HIP 28368*: NN 3371 A has a high proper motion (pm of 0.253″/yr in the direction 177°, ESA 1997). The star was first treated as a double in the Hipparcos Catalogue (DMSA/X), but later on reprocessed as a single star ($\pi_{\rm Hip}$ = 74.17 ± 1.82 mas). No new component at a separation above 1.7″ was found in the vicinity. Component B, situated at (119.6°, 161.2″), was not in the field of view centred on the primary.

*HIP 29316*: GJ 228 AB has a huge proper motion (pm of 0.970″/yr in the direction 176° and $\pi_{\rm tr}$ = 97.9 ± 3.9 mas, van Altena et al. 1995), definitely M-type (orbital) motion. There is a notable difference in angular separation with the Hipparcos double-star solution.

*HIP 31635*: GJ 239 A has a huge proper motion (pm of 0.844″/yr in the direction 293°, ESA 1997), definitely with L-type motion due to the large differential proper motion between the "components". It furthermore has no Hipparcos double-star solution ($\pi_{\rm Hip}$ = 101.59 ± 2.35 mas).

*HIP 34222*: GJ 265 A has a significant proper motion (pm of 0.122″/yr in the direction 205°, van Altena et al. 1995), definitely L-type motion based on our measurements obtained at two different epochs. It has no Hipparcos double-star solution ($\pi_{\rm Hip}$ = 41.63 ± 2.16 mas).

*HIP 39721*: Wo 9251 AB has a significant proper motion (pm of 0.136″/yr in the direction 181°, van Altena et al. 1995), possibly M-type ($\pi_{\rm Hip}$ = 24.85 ± 3.92 mas). There is a notable difference in angular separation with the Hipparcos double-star solution.

*HIP 39896*: GJ 1108 AB (pm of 0.196″/yr in the direction 195°, van Altena et al. 1995) has a wrong Hipparcos double-star solution ($\pi_{\rm Hip}$ = 48.26 ± 3.16 mas). Our two measurements are, however, consistent with the older CCDM data at a separation of 13″. It is also the variable star FP Cnc.

*HIP 41824*: GJ 2069 AB has a significant proper motion (pm of 0.246″/yr in the direction 249° and $\pi_{\rm Hip}$ = 78.05 ± 5.69 mas, ESA 1997). It has no Hipparcos double-star solution (but is in DMSA/V). Component A is the variable star CU Cnc. Compared to the older data, the configuration is almost similar. Both components (=NLTT 19685 and 19684) form a common proper-motion binary (Luyten 1979). This system is actually quintuple with three recently resolved new close components (Beuzit et al. 2004).

*HIP 43422*: GL 323 AB has a significant proper motion (pm of 0.146″/yr in the direction 271° and $\pi_{\rm Hip}$ = 31.24 ± 19.30 mas, ESA 1997). It has a Hipparcos stochastic solution only (DMSA/X). It may present orbital motion.

*HIP 44295*: GJ 1120 AB is a nearby system with a high proper motion (pm of 0.343″/yr in the direction 201° (van Altena et al. 1995) and $\pi_{\rm Hip}$ = 54.57 ± 3.21 mas). A clear binary motion was detected. From a comparison of our two measurements and the Hipparcos double-star solution, we obtain a decrease of 0.2°/yr in position angle, fully consistent with the rate of change detected by Hipparcos.

*HIP 92836*: GJ 734 AB is a nearby system with a significant proper motion (pm of 0.120″/yr in the direction 95° and $\pi_{\rm tr}$ = 61.5 ± 7.6 mas, van Altena et al. 1995). Orbital motion is possibly detected. One component is variable (V1436 Aql). The Hipparcos stochastic solution was rejected because it had a cosmic error greater than 100 mas (ESA 1997). It was reprocessed as a single star later on (pm of 0.120″/yr in the direction 9° and $\pi_{\rm Hip}$ = 50.30 ± 2.70 mas).

*HIP 95071*: GL 754.1 BA is a nearby system with a significant proper motion (pm of 0.199″/yr in the direction 198° and $\pi_{\rm tr}$ = 99.2 ± 2.5 mas, van Altena et al. 1995). Component B (= NLTT 47693) is variable (NSV 11920). It has a Hipparcos stochastic solution only (DMSA/X) ($\pi_{\rm Hip}$ = 89.08 ± 7.16 mas). Orbital motion is clearly detected between components B and Q. There is a fainter common proper-motion companion showing an almost fixed configuration over more than a century (comp A = NLTT 47691) (Gould & Chaname 2004).

*HIP 97237*: GL 766 AB has a huge proper motion (total pm of 1.226″/yr in the direction 181° and $\pi_{\rm tr}$ = 94.7 ± 4.4 mas (van Altena et al. 1995)). The orbital motion with respect to 40 years ago is clearly detected with a rate of change of 0.5°/yr in position angle. The Hipparcos stochastic solution was rejected because it had a cosmic error greater than 100 mas (ESA 1997). Two orbits exist for this binary (Kui 95) in the literature. From the comparison in Table 7, only the orbit by Söderhjelm (1999) ($P_{\rm orb}$ = 228 yr) is reliable (ΔPos = 0.1″).

*HIP 101150*: Wo 9697 AB is a nearby system with a significant proper motion (pm of 0.195″/yr in the direction 228° (van Altena et al. 1995) and $\pi_{\rm Hip}$ = 43.24 ± 4.37 mas). We were not able to resolve the orbiting companion at a separation below 1″ (ESA 1997). The position of the known component C has shifted due to the high differential proper motion over the last 40 years (see also the different parallax attributed by van Altena et al. 1995). Another "component" (D′) was measured, but it has no link with the known component D. This binary needs further monitoring using the speckle-interferometric technique.

*HIP 104210*: shows a distinct motion of L-type. Previous analysis of all available data (Mason et al. 2001) suggested that this is an optical pair. Using the colour difference between the components, we concluded that the secondary is a foreground star probably lying within 100 pc (Strigachev et al. 2001). The difference in relative position of about 0.7″ with the Hipparcos value is entirely caused by the differential proper motion (0.089″/yr in the direction 40°) over the interval of 7.5 years (ESA 1997).

*HIP 105421*: is a fixed system. The errors are much smaller than those of the Hipparcos Catalogue.

*HIP 108888*: is most probably a fixed system. Component A is the variable star V394 Lac. This measurement does not agree with the Hipparcos double-star solution. However, the difference in relative position is very probably due to a gridstep ambiguity affecting the determination of $\rho_{\rm Hip}$.

*HIP 108892*: $\Delta\rho$ is a bit large for a fixed system (though only at the $2\sigma_{\rm Hip}$-level). Our two observations do concord in angular separation, but not in position angle. One component is the pulsating variable star V378 Lac. In view of the overall consistency with the old CCDM relative position however, it probably is a fixed system.

*HIP 110326*: shows a distinct motion of L-type. There is a difference in relative position of about 0.4″ with the Hipparcos value (ESA 1997). It is most probably an optical pair whose components are moving apart at the relative speed of about 0.06–0.07″/yr.

*HIP 110640*: GL 857.1 AB has a significant proper motion (pm of 0.200″/yr in the direction 244° (van Altena et al. 1995) and $\pi_{\rm Hip}$ = 46.74 ± 1.66 mas). The orbital motion was described in Paper II. The position of component C has shifted in agreement with the high differential proper motion over more than one century. Our differential photometric data, however, indicates that "component" C is about 1 mag fainter than expected.

*HIP 111279*: is probably a fixed system. Component A is HIP 111277 for which the Hipparcos stochastic solution was rejected because it had a cosmic error greater than 100 mas (ESA 1997). The difference with the double-star solution proposed by Hipparcos (DMSA/C) approximates 1 gridstep. Our measurements agree very well with the older CCDM data.

*HIP 113411*: is perhaps a fixed system. Our observation does not agree with the Hipparcos solution even though this target has insignificant proper motion. The accuracy of our measurement is not very high, therefore an extra observation is needed to confirm whether some kind of relative motion is present or not.

*HIP 113437*: has a significant proper motion (pm of 0.096″/yr in the direction 74° and $\pi_{\rm Hip}$ = 8.19 ± 1.52 mas). Orbital motion has probably been detected since $\Delta\theta$ is important.

*HD 23713*: Cou 80 AB has an intermediate proper motion (pm of 0.041″/yr in the direction 166° and $\pi_{\rm tr}$ = 45.0 ± 15.0 mas, van Altena et al. 1995). The comparison with older CCDM data indicates orbital motion.

*GJ 1047 AB*: (=NLTT 7710) has a huge proper motion (pm of 0.919″/yr in the direction 128° and $\pi_{\rm tr}$ = 46.2 ± 3.6 mas). Component C (=NLTT 7708) shares the same proper motion (van Altena et al. 1995).

*GJ 1103 AB*: has a high proper motion (pm of 0.766″/yr in the direction 161° and $\pi_{\rm tr}$ = 114.0 ± 3.3 mas, van Altena et al. 1995). Component B (=NLTT 18546) formerly situated at (78.0°, 3.0″) forms a common proper-motion pair with component A (=NLTT 18545) (Luyten 1979), but was not detected (with $\Delta m_R \approx 2.5$ mag). The other "components" (C′, D′, E′) have no physical link with the binary system.

*GJ 1245 AB*: has a high proper motion (pm of 0.731″/yr in the direction 143° and $\pi_{\rm tr}$ = 220.2 ± 1.0 mas, van Altena et al. 1995) and shows a clear orbital motion. Component B (=NLTT 48414) forms a common proper-motion pair with component A (=NLTT 48415) (Luyten 1979) and shows a slight change in position angle since 1997. There is a low mass companion (estimated to 0.1 $M_\odot$) close to GJ 1245 A (Gliese & Jahreiss 1991).