Extrasolar planets in stellar multiple systems
(Research Note)

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ABSTRACT

Aims. Analyzing exoplanets detected by radial velocity (RV) or transit observations, we determine the multiplicity of exoplanet host stars in order to study the influence of a stellar companion on the properties of planet candidates.

Methods. Matching the host stars of exoplanet candidates detected by radial velocity or transit observations with online multiplicity catalogs in addition to a literature search, 57 exoplanet host stars are identified having a stellar companion.

Results. The resulting multiplicity rate of at least 12% for exoplanet host stars is about four times smaller than the multiplicity of solar like stars in general. The mass and the number of planets in stellar multiple systems depend on the separation between their host star and its nearest stellar companion, e.g. the planetary mass decreases with an increasing stellar separation. We present an updated overview of exoplanet candidates in stellar multiple systems, including 15 new systems (compared to the latest summary from 2009).

Key words. planets and satellites: general – binaries: general – planetary systems

1. Introduction

More than 700 extrasolar planet (exoplanet) candidates were discovered so far (Schneider et al. 2011, http://www.exoplanet.eu), but the knowledge of their properties is strongly affected by observational bias and selection effects. Taking the solar system as an archetype, the target lists of exoplanet search programs so far originally consist of mostly single and solar like stars (regarding the spectral type and age). But the first planet candidate detected by the RV technique was found around the primary of the close spectroscopic binary γ Cep (Campbell et al. 1988; Hatzes et al. 2003; Neuhäuser 2009, and references therein), which demonstrates the existence of planets in binaries.

In the last years, imaging campaigns found stellar companions around several dozen exoplanet host stars formerly believed to be single stars (see e.g. Raghavan et al. 2006; Mugrauer & Neuhäuser 2009, and references therein). Most of these exoplanet candidates are in the S-type orbit configuration (exoplanet surrounding one stellar component of a binary), while the orbit of a planet around both stellar binary components is called P-type orbit. Such circumbinary planets are detectable by measuring eclipse timing variations as done for NN Ser (Beuermann et al. 2010), HW Vir (Lee et al. 2009), DP Leo (Qian et al. 2010), HU Aqr (Qian et al. 2011; Hinse et al. 2012), and UZ For (Dai et al. 2010; Potter et al. 2011). Kepler-16 (AB)b, Kepler-34 (AB)b, and Kepler-35 (AB)b are detected by measuring the transit lightcurve and eclipse timing variations (Doyle et al. 2011; Welsh et al. 2012), thus these are confirmed circumbinary planets. Due to a different formation and evolution scenario for planets in a P-type orbit (compared to the more common S-type orbit), this paper only considers exoplanets found in a S-type orbit

Multiplicity studies, as done by Mugrauer et al. (2007b) or Eggenberger et al. (2007), are looking for stellar companions around exoplanet host stars by direct imaging. As summarized in Mugrauer & Neuhäuser (2009), these studies found 44 stellar companions around stars previously not known to be multiple, which results in a multiplicity rate of about 17%, while Raghavan et al. (2006) found a host star multiplicity of about 23%. The multiplicity rate of solar like stars1 was determined by Raghavan et al. (2010) to (46 ± 2)%. Duquennoy & Mayor (1991) measured the multiplicity of 164 nearby G-dwarfs (within 22 pc) to 44% (57% considering incompleteness).

2. Extrasolar planets in stellar multiple systems

The deuterium burning minimum mass (DBMM) of 13 MJup is currently the most common criterion to distinguish a brown dwarf from a planet. However, we make use of the Extrasolar Planets Encyclopaedia (EPE) in this paper and thus apply the definition of Schneider et al. (2011) who includes all confirmed substellar companions with a mass of less than 25 MJup within a 1σ uncertainty. Due to a missing publication of the planet detection, the exoplanet candidates GJ 433 b, ρ CrB b, 91 Aqr b, ν Oph b+c, τ Gem b, HD 59686 b, HD 106515 A b, HD 20781 b+c, and HD 196067 b are not included in this paper. Also, the stellar binary HD 176051, where Buterspaugh et al. (2010) detected the astrometric signal of an exoplanet around one of the two stellar components, is not included in this study: Because the planet was found by ground based astrometric observation (using an optical interferometer), this detection still need to be confirmed by other techniques and the final planetary mass depends on which of the stellar components is the host star.

The multiplicity of an exoplanet host star is defined (in this paper) by either a published common proper motion or an entry in the Catalogue of Components of Double and Multiple Stars

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1 Defined as all main-sequence stars with a spectral type from F6 to K3 within 25 parsec, see Raghavan et al. (2010).
etary masses. The probability distribution function (PDF) and the expectation value $\hat{\mu}$ of a log-normal distribution for a measure $x$ can be calculated by

$$PDF(x, \mu, \sigma) = \frac{e^{-(\log(x) - \mu)^2 / (2\sigma^2)}}{x\sigma\sqrt{2\pi}}$$

where $\mu$ and $\sigma$ are the mean value and the standard deviation of the distribution. To determine the $\chi^2$ value (shown in Fig. 2) the Python package “SciPy” (Jones et al. 2001) was used.

As one can see in Fig. 2, the log-normal fit results in a better $\chi^2_{red}$ than the power-law fit. The expectation values for the mass of exoplanets around single stars and in stellar multiple systems differ, hence the power-law as well as the log-normal fit lead to the conclusion that the mass distribution of exoplanets in stellar multiple systems are pushed towards higher planetary masses, compared to the mass distribution of exoplanets around single stars. However, the statistic of the exoplanet host star multiplicity is still affected by observational bias and selection effects of the originally planet search programs. Most multiplicity studies so far were carried out after the planet detection. Hence, most of the host stars are solar like (regarding the age and spectral type), but they are also originally selected as single stars. To avoid the

### Table 1. Multiplicity of solar like and exoplanet host stars.

| Multiple | Single | Double | Triple or higher | Reference |
|----------|--------|--------|------------------|-----------|
| solar like stars |
| 46% | 54% | 34% | 9% | 1 |
| 44% | 56% | 38% | 4% | 2 |
| exoplanet host stars |
| 22.9% | 77.1% | 19.8% | 3.1% | 3 |
| 17.2% | 82.8% | 14.8% | 2.4% | 4 |
| 11.95% | 88.05% | 9.85% | 2.1% | 5 |

### References.
1) Raghavan et al. (2010); 2) Duquennoy & Mayor (1991); 3) Raghavan et al. (2006); 4) Mugrauer & Neuhäuser (2009); 5) this work.

(CCDM) by Dommanget & Nys (2000). In case, the stellar multiplicity is only mentioned in the CCDM, all stellar components were checked on common proper motion using other catalogs (see Appendix A). By searching the literature and matching the host stars of exoplanet candidates detected with transit or RV observations listed in the EPE (date: 2012/02/08) with the CCDM, 57 stellar multiple systems (47 double and 10 triple systems) with at least one exoplanet out of 477 systems in total are identified. The resulting multiplicity rate of about 12% is less than previously published values (see Table 1). An explanation for that can be the increasing number of transiting exoplanets in the last years, which are included in this paper but excluded by previous studies. The host star multiplicity of transiting exoplanets is most likely still underestimated, because multiplicity studies around such host stars, like done by Daemgen et al. (2009), have just recently started.

The complete list of the 57 multiple systems harboring exoplanet candidates can be found in Tables A.4–A.6. Furthermore, the proper motions of all these stars gathered from online catalogs are shown in Tables A.1–A.3. The latest published summary, done by Mugrauer & Neuhäuser (2009), listed 44 planetary systems in a stellar multiple system. However, two of these systems are excluded in this study, namely HD 156846 AB (after 197 and 97, respectively. The mean of the planetary masses, compared to the mass distribution of exoplanets around single stars is still a effect of the observational bias and selection effects of the originally planet search programs. Most multiplicity studies so far were carried out after the planet detection. Hence, most of the host stars are solar like (regarding the age and spectral type), but they are also originally selected as single stars. To avoid the

### Fig. 1. The (minimum) mass of extrasolar planets detected by RV (circles) or transit (squares) observations over their orbital period. Exoplanets around single stars are shown as open markers, while exoplanets in stellar multiple systems are coded by filled symbols. Jupiter is shown as a filled triangle and the filled diamond marks Neptune.

### Fig. 2. Mass distribution of exoplanets detected by RV or transit observations around single stars (left column), in stellar multiple systems (middle column), and for all kind of host stars (right column) fitted by a power law (dashed line, upper values) and a log-normal distribution (solid line, lower values).
adaption of such selection effects, systematic searches for planets in stellar multiple systems, like described in Desidera et al. (2007) or Roell et al. (2010), are needed.

4. Influence of a close stellar companion on planet properties

In the previous section, the difference in the mass of exoplanets around single stars and in stellar multiple systems was discussed. In order to unveil the cause of this difference, a closer look on the influence of a stellar companion around the exoplanet host star is advisable. In Fig. 3 we plot the planetary (minimum) mass over the projected separation of the exoplanet host star and its nearest stellar companion. Because all systems analyzed in this paper are hierarchical, the exoplanet host star and its nearest stellar companion can be treated as a binary system. The order of the stellar multiplicity is not relevant, but the planetary minimum mass decreases with an increasing projected stellar separation (dashed line in Fig. 3). Furthermore, multi-planet systems are only present in stellar systems with a projected separation larger than about 100 AU and up to now, no planet was found in a stellar binary with a projected separation of less than 10 AU. The two planets below the dashed line in Fig. 3 are the planetary system around GJ 667 C, a component of a hierarchical triple star system at a distance of 7 pc. The true semi-major axis is likely larger than the measured projected separation and the true planetary mass could also be larger than the measured minimum mass. These observational bias effects could explain, why GJ 667 C is the only system left of that dashed line in Fig. 3.

Holman & Wiegert (1999) determine a formula to calculate the critical semi-major axis $a_{\text{crit}}$ for a stable planetary orbit coplanar to the stellar orbit with the semi-major axis $a_{\text{bin}}$, which varies from $a_{\text{crit}} \approx (0.02 \ldots 0.45) a_{\text{bin}}$, depending on the mass ratio $\rho_{\text{bin}}$ and the eccentricity $e_{\text{bin}}$ of the stellar binary. Table 2 listed the five systems, where the apparent separation is less than 50 times the planetary semi-major axis (see Fig. 4) including the corresponding critical semi-major axis. Except for the exoplanet HD 196885 Ab, which grazes an "unstable region" during the apastron passage, all these systems are clearly stable. However, considering the age of the F8V star HD 196885 A of 2.0 $\pm$ 0.5 Gyr (Correia et al. 2008), the planetary system can also be regarded as long-term stable.

5. Summary

Analyzing the host star multiplicity of exoplanets detected by RV or transit observations, 57 exoplanet host stars with stellar companions are identified and presented in the Appendix A, including 15 new systems (compared to the latest published summary in 2009). The resulting multiplicity rate for exoplanet host stars of at least 12% is about four times smaller than the multiplicity of solar like stars. No planet is found so far in stellar binaries with a projected separation of less than 10 AU and multi-planet systems were only found in stellar systems with a projected separation larger than 100 AU. The planetary (minimum) mass decreases with an increasing projected stellar separation.

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Table 2. Critical semi-major axis $a_{\text{crit}}$ for planets in close stellar binaries, calculated according to Holman & Wiegert (1999).

| Host star | $M_{\text{host}}$ | $M_{\text{comp}}$ | $e_{\text{bin}}$ | $a_{\text{bin}}$ | $a_{\text{crit}}$ | $e_{\text{pl}}$ | $a_{\text{pl}}$ | $e_{\text{pl}}$ | References |
|-----------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-------------|
| $\gamma$ Cep A | 1.40 | 0.41 | 0.23 | 0.41 | 20.2 | 3.86 | 0.05 | 2.05 | 2.15 | Neuhauser et al. (2007) |
| HD 41004 A | 0.70 | 0.42 | 0.38 | 0.40 | 20.0 | 3.38 | 0.39 | 1.60 | 2.28 | Chauvin et al. (2011) |
| HD 196885 A | 1.33 | 0.45 | 0.25 | 0.42 | 21.0 | 3.84 | 0.48 | 2.60 | 3.85 | Chauvin et al. (2011) |
| HD 126614 A | 1.15 | 0.32 | 0.22 | ≤0.6 | 36.2 | ≥4.24 | 0.41 | 2.35 | 3.13 | Howard et al. (2010) |
| HD 19994 A | 1.34 | 0.90 | 0.40 | 0.09 | ~100 | ~31 | 0.30 | 1.42 | 1.85 | Roell et al. (2011); Mayor et al. (2004) |

Notes. (a) HD 19994 B itself is a close stellar binary with a total mass of $M_{\text{tot}} = 0.9 M_\odot$ (Roell et al. 2011). (b) Values for eccentricity and semi-major axis of HD 19994 are taken from Eggenberger et al. (2004).
# Updated tables of extrasolar planets in stellar multiple systems

Table A.1: Exoplanet host stars having a common proper motion with another star. The ID of the host stars is the same as it is used in the EPE and the planet status is coded by R ... published in a Refereed paper, S ... Submitted to a professional journal, and C ... announced by astronomers in professional Conferences. A planet status followed by the letter R in brackets means, the status on the EPE is not up-to-date and the planet detection is already published in a refereed paper. The fourth and fifth column show the proper motion listed in the catalog mentioned in the last column. For easy identification of the stellar companions in the online catalogs, the third column contains either the separation from the primary as calculated by the used online catalog or the latest separation measurement in case of published relative astrometric measurements.

| System | EPE planet status | \( r [\text{'}] \) | \( \mu_\alpha \cos \delta [\text{mas/year}] \) | \( \mu_\delta [\text{mas/year}] \) | Catalogue |
|--------|-------------------|----------------|---------------------------------|---------------------------------|-----------|
| 11 Com A | R | 9 | \(-109.37 \pm 1.26\) | \(82.95 \pm 0.75\) | ASCC-2.5-V3 |
| 11 Com B | – | – | \(-109 \pm \text{n.s.}\) | \(85 \pm \text{n.s.}\) | CCDM |
| 16 Cyg A | – | – | \(-133.39 \pm 0.82\) | \(-163.08 \pm 0.85\) | ASCC-2.5-V3 |
| 16 Cyg B | R | 39.44 | \(-147.77 \pm 0.85\) | \(-158.39 \pm 0.76\) | ASCC-2.5-V3 |
| 16 Cyg C | – | | | close C component about 3.4'' away from A, see | Patience et al. (2002) |
| 30 Ari A | – | – | \(137.66 \pm 0.74\) | \(-14.98 \pm 0.91\) | ASCC-2.5-V3 |
| 30 Ari B | R | 36.86 | 145.33 \pm 1.21 | \(-12.86 \pm 0.94\) | ASCC-2.5-V3 |
| 55 Cnc A | R | – | \(-485.4 \pm 0.9\) | \(-234.4 \pm 0.7\) | Nomad-1 |
| 55 Cnc B | – | 84.16 | \(-488.0 \pm 6.0\) | \(-234.0 \pm 5.0\) | Nomad-1 |
| 91 Aqr A | S | – | \(370.70 \pm 0.63\) | \(-16.22 \pm 0.7\) | ASCC-2.5-V3 |
| 91 Aqr B | – | 51.93 | \(373.00 \pm 2.41\) | \(-18.46 \pm 2.41\) | ASCC-2.5-V3 |
| 91 Aqr C | – | 52.03 | \(370.00 \pm 1.87\) | \(-20.34 \pm 0.98\) | ASCC-2.5-V3 |
| 91 Aqr D | – | 106.67 | \(18.3 \pm 8.4\) | \(-10.5 \pm 7.8\) | Nomad-1 |
| 91 Aqr E | – | 88.05 | \(-9.4 \pm 8.7\) | \(-25.2 \pm 7.8\) | Nomad-1 |
| \(\gamma\) Cep A | R | – | \(-48.8 \pm 0.4\) | \(-127.1 \pm 0.4\) | Nomad-1 |
| \(\gamma\) Cep B | – | | | \(\text{imaged directly by Neuhäuser et al. (2007)}\) | |
| \(\gamma\) Leo A | R | – | \(306.35 \pm 3.27\) | \(-160.77 \pm 2.30\) | ASCC-2.5-V3 |
| \(\gamma\) Leo B | – | 4.33 | \(309.60 \pm 1.32\) | \(-152.91 \pm 0.75\) | ASCC-2.5-V3 |
| \(\gamma\) Leo C | – | 325.15 | \(-501.30 \pm 1.05\) | \(-41.97 \pm 1.28\) | ASCC-2.5-V3 |
| \(\gamma\) Leo D | – | 366.86 | \(-10.01 \pm 1.53\) | \(-22.85 \pm 1.21\) | ASCC-2.5-V3 |
| \(r\) Boo A | R | – | \(-479.53 \pm 0.16\) | \(53.49 \pm 0.13\) | HIP-2 |
| \(r\) Boo B | – | 2.8 | | | confirmed by Duquennoy & Mayor (1991) |
| \(\nu\) And A | R | – | \(-172.5 \pm 0.5\) | \(-381.0 \pm 0.4\) | Nomad-1 |
| \(\nu\) And B | – | 55 | | | confirmed by Lowrance et al. (2002) |
| \(\nu\) And C | – | 110.27 | \(-9.6 \pm 2.3\) | \(-3.5 \pm 2.3\) | Nomad-1 |
| \(\nu\) And D | – | 273.20 | \(-16.3 \pm 0.7\) | \(-4.7 \pm 0.6\) | Nomad-1 |
| GJ 667 AB | – | – | \(-1129.76 \pm 9.72\) | \(-77.02 \pm 4.67\) | HIP-2 |
| GJ 667 C | R | 32.66 | 1049.0 \pm \text{n.s.} | \(-91.0 \pm \text{n.s.}\) | UCAC-3 |
| GJ 667 C | – | 32.75 | 1155.0 \pm 7.2 | \(-214.4 \pm 9.5\) | NOMAD-1 |

GJ 667 C has not a common proper motion within the measurement errors, but it can be ruled out as a background object. The large spread in the proper motion measurements can be possibly explained by the fact, that the AB component influences the relative astrometric measurements of the (AB)\&C pair.
Table A.1. continued.

| System         | EPE planet status | $r$ [°] | $\mu_\alpha$ cos $\delta$ [mas/year] | $\mu_\delta$ [mas/year] | Catalogue         |
|----------------|------------------|--------|---------------------------------------|--------------------------|-------------------|
| HD 20782 A     | R                | –      | 349.85 ± 0.80                         | – 65.0 ± 1.07            | ASCC-2.5 V3       |
| HD 27442 A     | R                | –      | 349.76 ± 1.13                         | – 68.44 ± 1.57           | ASCC-2.5 V3       |
| HD 27442 B     | R                | 13.06  | – 48.09 ± 0.80                        | – 166.69 ± 0.77          | ASCC-2.5 V3       |
| HD 28254 A     | S(R)             | –      | – 66.9 ± 0.6                          | – 144.0 ± 0.6            | ASCC-2.5 V3       |
| HD 28254 B     | R                | 4.3    | – 79.22 ± 1.02                        | – 142.22 ± 1.00          | ASCC-2.5 V3       |
| HD 38529 A     | R                | –      | – 283.72 ± 14.50                      | – 117.47 ± 14.80         | ASCC-2.5 V3       |
| HD 38529 B     | R                | –      | 193.77 ± 0.95                         | – 153.36 ± 0.70          | ASCC-2.5 V3       |
| HD 40979 A     | R                | –      | 94.08 ± 0.85                          | – 153.11 ± 1.65          | ASCC-2.5 V3       |
| HD 40979 BC    | R                | –      | 94.08 ± 0.85                          | – 153.11 ± 1.65          | ASCC-2.5 V3       |
| HD 41004 A     | R                | –      | 41.72 ± 1.19                          | – 64.87 ± 1.34           | ASCC-2.5 V3       |
| HD 41004 B     | R                | 1.19   | 42.25 ± 1.08                          | 65.16 ± 1.12             | ASCC-2.5 V3       |
| HD 46375 A     | R                | 10.35  | 114.2 ± 0.9                           | – 96.7 ± 0.7             | ASCC-2.5 V3       |
| HD 65216 A     | R                | –      | – 122.66 ± 1.34                       | 145.77 ± 1.15            | ASCC-2.5 V3       |
| HD 65216 BC    | R                | 7.14   | 122.66 ± 1.34                         | 145.77 ± 1.15            | ASCC-2.5 V3       |
| HD 75289 A     | R                | –      | – 19.90 ± 0.66                        | – 228.13 ± 0.73          | ASCC-2.5 V3       |
| HD 75289 B     | R                | 21.47  | 56.84 ± 1.37                          | 10.02 ± 1.71             | ASCC-2.5 V3       |
| HD 80606 A     | R                | 20.18  | 51.95 ± 1.32                          | 9.97 ± 1.77              | ASCC-2.5 V3       |
| HD 80606 B     | R                | 20.18  | 51.95 ± 1.32                          | 9.97 ± 1.77              | ASCC-2.5 V3       |
| HD 89744 A     | R                | –      | – 120.12 ± 0.85                       | 138.66 ± 0.76            | ASCC-2.5 V3       |
| HD 89744 B     | R                | 62.99  | 120.12 ± 0.85                         | 138.66 ± 0.76            | ASCC-2.5 V3       |
| HD 99491 A     | R                | –      | – 725.22 ± 0.64                       | 180.30 ± 0.72            | ASCC-2.5 V3       |
| HD 99492 A     | R                | 33.27  | – 727.57 ± 1.55                       | 186.47 ± 1.55            | ASCC-2.5 V3       |
| HD 99492 B     | R                | 204.56 | 5.36 ± 1.98                           | – 13.72 ± 2.00           | ASCC-2.5 V3       |
| HD 101930 A    | R                | –      | 15.42 ± 1.30                          | 348.29 ± 1.27            | ASCC-2.5 V3       |
| HD 101930 B    | R                | 69.89  | 24.98 ± 4.01                          | 351.54 ± 2.35            | ASCC-2.5 V3       |
Table A.1. continued.

| System        | EPE planet status | $r'_{\text{Bar}}$ | $\mu_\alpha \cos \delta$ [mas/year] | $\mu_\delta$ [mas/year] | Catalogue                  |
|---------------|-------------------|-------------------|-------------------------------------|--------------------------|----------------------------|
| HD 109749 A   | C(R)              | –                 | $-156.69 \pm 1.47$                 | $-4.88 \pm 1.54$         | ASCC-2.5 V3               |
| HD 109749 B   | –                 | 8.42              | $-157.88 \pm 1.42$                 | $-5.46 \pm 1.28$         | ASCC-2.5 V3               |
| HD 114729 A   | R                 | –                 | $-200.83 \pm 1.23$                 | $-307.82 \pm 1.11$       | ASCC-2.5 V3               |
| HD 114729 B   | –                 | 8.05              | confirmed by Mugrauer et al. (2005) |                         |                            |
| HD 114762 A   | R                 | –                 | $-582.75 \pm 1.12$                 | $-1.04 \pm 1.07$         | ASCC-2.5 V3               |
| HD 114762 B   | –                 | 3.26              | confirmed by Patience et al. (2002) |                         |                            |
| HD 125612 A   | S(R)              | –                 | $-62.25 \pm 1.66$                  | $-67.63 \pm 1.50$        | ASCC-2.5 V3               |
| HD 125612 B   | –                 | 89.99             | confirmed by Mugrauer & Neuhäuser (2009) |                      |                            |
| HD 126614 AB  | S(R)              | –                 | $-151.66 \pm 1.35$                 | $-148.66 \pm 1.22$       | ASCC-2.5 V3               |
|               |                   |                   | –                                   | $-152.4 \pm 1.0$         | $-148.1 \pm 0.9$          |
|               |                   |                   | B is 0.5'' away from A, found by Howard et al. (2010) and common proper motion confirmed by Ginski et al. (2012) | | |
| HD 126614 C   | –                 | 41.80             | $-144.0 \pm 4.0$                   | $-142.0 \pm 3.0$         | Nomad-1                   |
| HD 132563 A   | –                 | –                 | $-56.38 \pm 2.22$                  | $-68.87 \pm 1.69$        | ASCC-2.5 V3               |
| HD 132563 B   | R                 | 3.79              | $-57.15 \pm 2.11$                  | $-69.18 \pm 1.62$        | ASCC-2.5 V3               |
| HD 132563 C   | –                 | 64.77             | $-14.52 \pm 1.57$                  | 7.36 \pm 1.02            | ASCC-2.5 V3               |
| HD 137388 A   | R                 | –                 | $-46.72 \pm 0.89$                  | 43.31 \pm 0.97           | HIP-2                     |
| HD 137388 B   | –                 | 21.31             | $-35.54 \pm 14.33$                 | 74.43 \pm 16.63          | HIP-2                     |
|               |                   | 21.32             | $-94.69 \pm 58.77$                 | 58.04 \pm 63.18          | ASCC-2.5 V3               |
| HD 142022 A   | R                 | –                 | $-340.52 \pm 0.91$                 | $-31.04 \pm 1.01$        | ASCC-2.5 V3               |
| HD 142022 B   | –                 | 22.85             | $-359.70 \pm 2.38$                 | $-26.28 \pm 2.04$        | ASCC-2.5 V3               |
| HD 147513 A   | R                 | –                 | $-72.47 \pm 0.93$                  | 3.43 \pm 0.83            | ASCC-2.5 V3               |
| HD 147513 B   | –                 | 345.69            | $-76.73 \pm 2.17$                  | 1.94 \pm 2.10            | ASCC-2.5 V3               |
| HD 177830 A   | R                 | –                 | $-40.83 \pm 0.75$                  | $-50.13 \pm 0.99$        | ASCC-2.5 V3               |
| HD 177830 B   | –                 | 1.65              | confirmed by Eggenberger et al. (2007) | | | |
| HD 178911 A   | –                 | –                 | 50.20 \pm 1.87                      | 190.05 \pm 2.46          | ASCC-2.5 V3               |
|               |                   |                   | 51.89 \pm 2.09                      | 196.24 \pm 2.31          | HIP-2                     |
| HD 178911 B   | R                 | 16.86             | 67.13 \pm 2.11                      | 190.50 \pm 2.64          | ASCC-2.5 V3               |
|               |                   | 16.85             | 55.14 \pm 3.43                      | 201.30 \pm 4.39          | HIP-2                     |
| HD 185269 A   | R                 | –                 | $-32.3 \pm 0.5$                     | $-80.7 \pm 0.6$          | PPMXL                     |
| HD 185269 B   | –                 | 4.51              | confirmed by Ginski et al. (2012)   |                         |                            |
| HD 188015 A   | R                 | –                 | 55.61 \pm 0.12                      | $-91.62 \pm 1.11$        | ASCC-2.5 V3               |
| HD 188015 B   | –                 | 13                | confirmed by Raghavan et al. (2006) |                         |                            |
| HD 189733 A   | R                 | –                 | $-2.39 \pm 0.87$                    | $-250.19 \pm 0.80$       | ASCC-2.5 V3               |
| HD 189733 B   | –                 | 11.37             | confirmed by Bakos et al. (2006)    |                         |                            |
| HD 190360 A   | R                 | –                 | 683.3 \pm 0.4                       | $-524.0 \pm 0.5$         | Nomad-1                   |
| HD 190360 B   | –                 | 178.00            | 686.8 \pm 4.1                       | $-530.3 \pm 4.1$         | Nomad-1                   |
| HD 195019 A   | R                 | –                 | 349.54 \pm 1.12                     | $-57.27 \pm 0.82$        | ASCC-2.5 V3               |
| HD 195019 B   | –                 | Multiplicity first mentioned by Fischer et al. (1999) | | | |
| HD 196050 A   | R                 | –                 | $-191.30 \pm 0.85$                 | $-63.31 \pm 0.99$        | ASCC-2.5 V3               |
| HD 196050 BC  | –                 | 10.88             | confirmed by Mugrauer et al. (2005) | | | |
| HD 196885 A   | R                 | –                 | 47.4 \pm 0.8                        | 83.0 \pm 0.5             | Nomad-1                   |
| HD 196885 B   | –                 | 0.70              | confirmed by Chauvin et al. (2011)  |                         |                            |
| HD 196885 C   | –                 | 183.06            | $-5.2 \pm 1.4$                      | $-3.9 \pm 1.3$           | Nomad-1                   |
|               |                   | 183.12            | $-3.1 \pm 1.5$                      | $-2.2 \pm 1.4$           | Tycho-2                   |
| HD 204941 A   | R                 | –                 | $-298.24 \pm 1.34$                 | $-124.68 \pm 0.67$       | ASCC-2.5 V3               |
| HD 204941 B   | –                 | 53.62             | $-308.85 \pm 3.48$                  | $-124.13 \pm 1.84$       | ASCC-2.5 V3               |
Table A.1. continued.

| System     | EPE planet status | \( r [\prime] \) | \( \mu_\alpha \cos \delta \text{ [mas/year]} \) | \( \mu_\delta \text{ [mas/year]} \) | Catalogue          |
|------------|-------------------|------------------|---------------------------------|---------------------------------|-------------------|
| HD 212301 A | S(R)              | –                | –153.1 ± 0.6                    | –194.0 ± 0.4                    | Nomad-1           |
| HD 212301 B | –                 | 4.43             | –320.44 ± 0.12                  | –111.0 ± 0.8                    | Nomad-1           |
| HD 213240 A | R                 | –                | –145.4 ± 1.2                    | –111.0 ± 0.8                    | Nomad-1           |
| HD 22582 A  | –                 | 109.42           | –147.5 ± 4.4                    | –114.2 ± 4.4                    | Nomad-1           |

Table A.2. Exoplanet host stars listed in the CCDM, but unlikely a common proper motion pair (same columns as in A.1).

| System     | EPE planet status | \( r [\prime] \) | \( \mu_\alpha \cos \delta \text{ [mas/year]} \) | \( \mu_\delta \text{ [mas/year]} \) | Catalogue          |
|------------|-------------------|------------------|---------------------------------|---------------------------------|-------------------|
| 6 Lyn A    | R                 | –                | –30.0 ± 0.8                     | –338.8 ± 0.6                    | Nomad-1           |
| 6 Lyn B    | –                 | 169.91           | 3.6 ± 1.6                      | 7.2 ± 1.6                       | Nomad-1           |
| 18 Del A   | R                 | –                | –47.9 ± 0.7                     | –34.3 ± 0.3                     | Nomad-1           |
| 18 Del B   | –                 | 197.34           | 10.8 ± 1.1                     | –12.6 ± 1.2                     | Nomad-1           |
| 18 Del C   | –                 | 235.69           | –6.3 ± 1.6                     | –6.4 ± 3.2                      | Nomad-1           |
| 61 Vir A   | R                 | –                | –1070.00 ± 0.66                 | –1064.22 ± 0.49                 | ASCC-2.5 V3       |
| 61 Vir B   | –                 | 365.42           | –31.65 ± 3.71                  | –13.56 ± 2.26                   | ASCC-2.5 V3       |
| 70 Vir A   | R                 | –                | –234.8 ± 0.7                   | –576.1 ± 0.5                    | Nomad-1           |
| 70 Vir B   | –                 | 268.29           | 3.9 ± 1.3                      | 8.7 ± 0.9                       | Nomad-1           |
| \( \epsilon \) Tau A | R     | –                | 107.2 ± 1.0                     | –36.7 ± 0.8                     | Nomad-1           |
| \( \epsilon \) Tau B | –   | 189.16           | 23.1 ± 1.5                     | –18.9 ± 1.9                     | Nomad-1           |
| \( \kappa \) CrB A | –   | –                | –8.0 ± 0.5                     | –347.4 ± 0.6                    | Nomad-1           |
| \( \kappa \) CrB B | –   | 112.31           | –3.8 ± 5.4                     | –20.4 ± 5.4                     | Nomad-1           |
| \( \tau \) Gem A | C   | –                | –31.0 ± 1.0                    | –48.3 ± 0.5                     | Nomad-1           |
| \( \tau \) Gem B | –   | –                | proper motion not known        |                                 |                   |
| \( \tau \) Gem C | –   | 59.91            | –64.1 ± 9.0                    | –12.5 ± 9.0                     | Nomad-1           |
| HIP 75458 A | R     | –                | –8.2 ± 0.3                     | 17.3 ± 0.4                      | Nomad-1           |
| HIP 75458 B | –   | 253.77           | 0.5 ± 1.1                      | –5.5 ± 1.3                      | Nomad-1           |
| HD 33564 A | R                 | –                | –79.22 ± 0.52                  | 161.22 ± 0.62                   | ASCC-2.5 V3       |
| HD 33564 B | –                 | 24.47            | 52.00 ± 1.85                   | –156.6 ± 2.99                   | ASCC-2.5 V3       |
| HD 62509 A | R                 | –                | –625.6 ± 1.0                   | –45.9 ± 0.5                     | Nomad-1           |
| HD 62509 B | –                 | 30               | –45.0 ± 1.3                    | –128.1 ± 0.5                    | Nomad-1           |
| HD 62509 CD | –    | 248.98           | –4.5 ± 1.0                     | –3.7 ± 1.3                      | Nomad-1           |
| HD 62509 E | –                 | 281.26           | –3.1 ± 0.7                     | –14.0 ± 0.8                     | Nomad-1           |
| HD 62509 F | –                 | 304.84           | –6.5 ± 0.7                     | –2.3 ± 0.8                      | Nomad-1           |
| HD 62509 G | –                 | 152.77           | 6.0 ± 2.0                      | –4.5 ± 1.3                      | Nomad-1           |
| HD 81688 A | R                 | –                | –6.4 ± 0.6                     | –128.1 ± 0.5                    | Nomad-1           |
| HD 81688 B | –                 | 71.79            | –15.0 ± 1.0                    | –43.8 ± 1.1                     | Nomad-1           |
| HD 81688 C | –                 | 84.05            | –17.6 ± 1.1                    | –42.6 ± 0.7                     | Nomad-1           |
| HD 102365 A | R               | –                | –1530.55 ± 0.67                | 402.73 ± 0.62                   | ASCC-2.5 V3       |
| HD 102365 B | –               | 23.95            | 51.6 ± 4.4                     | –5.1 ± 4.3                      | UCAC-3            |
| HD 110014 A | R             | –                | –76.90 ± 0.54                  | –240.0 ± 0.55                   | ASCC-2.5 V3       |
| HD 110014 B | –             | 176.06           | –27.19 ± 1.82                  | –18.01 ± 1.80                   | ASCC-2.5 V3       |
| HD 110014 C | –             | 227.06           | –9.09 ± 1.44                   | –1.29 ± 2.75                    | ASCC-2.5 V3       |
| HD 110014 D | –             | 320.44           | –26.04 ± 1.26                  | –0.94 ± 0.64                    | ASCC-2.5 V3       |
| HD 121504 A | R             | –                | –250.5 ± 0.7                   | –84.0 ± 0.8                     | Nomad-1           |
| HD 121504 B | –             | 36.32            | –15.0 ± 1.5                    | 2.3 ± 1.4                       | Nomad-1           |
| HD 164922 A | R             | –                | 389.7 ± 0.5                    | –602.4 ± 0.5                    | Nomad-1           |
| HD 164922 B | –             | 96.39            | 6.4 ± 5.1                      | –3.9 ± 5.1                      | Nomad-1           |
| HD 164922 C | –             | 93.09            | –40.9 ± 5.2                    | –56.2 ± 4.1                     | UCAC-3            |
| HD 192263 A | R             | –                | –63.3 ± 1.6                    | 262.2 ± 0.7                     | Nomad-1           |
| HD 192263 BC | –            | 72.38            | 13.6 ± 1.2                     | 0.6 ± 1.7                       | Nomad-1           |
| HD 192263 D | –             | 78.44            | –4.3 ± 5.6                     | –7.9 ± 5.6                      | Nomad-1           |
Table A.3. Exoplanet host stars with companion candidates, but further epoch observations are needed (same columns as in A.1).

| System | EPE planet status | $\rho^*\cos\delta$ [mas/year] | $\mu_{\alpha}$ [mas/year] | $\mu_{\delta}$ [mas/year] | Catalogue |
|--------|-------------------|-------------------------------|--------------------------|--------------------------|-----------|
| WASP-2 A | S(R) | 4.9 ± 3.9 | -50.9 ± 6.7 | UCAC-3 |
| WASP-2 B | – | B is 0.76" away from A, second epoch needed, see Daemgen et al. (2009) |
| TrES-2 A | S(R) | 2.89 ± 2.50 | -3.40 ± 2.40 | ASCC-2.5 V3 |
| TrES-2 B | – | B is 1.09" away from A, second epoch needed, see Daemgen et al. (2009) |
| TrES-4 A | S(R) | -8.09 ± 4.80 | -33.00 ± 4.40 | ASCC-2.5 V3 |
| TrES-4 B | – | B is 1.56" away from A, second epoch needed, see Daemgen et al. (2009) |

Table A.4. Extrasolar planets detected with transit or RV observations in closer binaries with a projected stellar separation of $\rho_{app}^* \leq 1000$ AU, sorted by an increasing stellar separation. For the four closest systems a value for the binary semi-major axis ($a_{bin}$) is known from multi-epoch observations (listed in brackets in the $\rho_{app}^*$ column). If RV and transit measurements are available the true mass of the exoplanet candidate is given in the table.

| Note | Host star | $N_{pl}$ | $M_{pl}$ sin $i$ [M$_{Jup}$] | $a_{bin}$ [AU] | $\rho_{app}^*$ [AU] | Reference |
|------|-----------|----------|-----------------|----------------|----------------|-----------|
| †    | γ Cephei A | 1 | 1.6 (5…27) | 2.04 | 12.4 ($a_{bin} = 20.2$) | Campbell et al. (1988); Hatzes et al. (2003); Neuhäuser et al. (2007); Ruffert & Quirrenbach (2011) |
| ※    | Gl 86 A | 1 | 4.01 | 0.11 | 20.7 ($a_{bin} = 21$) | Queloz et al. (2000); Mugrauer & Neuhäuser (2005) |
| ※    | HD 41004 A | 1 | 2.54 | 1.64 | 21.5 ($a_{bin} = 20$) | Zucker et al. (2004); Raghavan et al. (2006) |
| ※    | HD 41004 B | 1 | 18.40 | 0.02 | 21.5 ($a_{bin} = 20$) | Zucker et al. (2003); Raghavan et al. (2006) |
| ※    | HD 196885 A | 1 | 2.58 | 2.37 | 23.1 ($a_{bin} = 21$) | Correia et al. (2008); Fischer et al. (2009); Chauvin et al. (2011) |
| ※    | τ Boo A | 1 | 3.90 | 0.05 | 45.2 | Butler et al. (1997); Raghavan et al. (2006) |
| ※    | GJ 3021 A | 1 | 3.37 | 0.49 | 68.6 | Naef et al. (2001b); Mugrauer et al. (2007a) |
| ※    | HD 177830 A | 1 | 1.28 | 1.00 | 100.3 | Vogt et al. (2000); Eggenberger et al. (2007) |
| ※    | HD 142 A | 1 | 1.03 | 1.00 | 105.0 | Tinney et al. (2002); Raghavan et al. (2006) |
| ※    | HD 114762 A | 1 | 11.02 | 0.30 | 134.0 | Latham et al. (1989); Mugrauer et al. (2005) |
| ※    | HD 195019 A | 1 | 3.70 | 0.14 | 149.2 | Fischer et al. (1999); Raghavan et al. (2006) |
| □    | γ′ Leo A | 1 | 8.78 | 1.19 | 165.6 | Han et al. (2010) |
| □    | HD 189733 A | 1 | 1.13 (true mass) | 0.03 | 220.0 | Bouchy et al. (2005); Eggenberger et al. (2007) |
| □    | HD 16141 A | 1 | 0.23 | 0.35 | 226.2 | Marcy et al. (2000); Mugrauer et al. (2005) |
| □    | HD 185269 A | 1 | 0.94 | 0.08 | 226.9 | Johnson et al. (2006); Ginski et al. (2012) |
| □    | HD 212301 A | 1 | 0.45 | 0.04 | 233.2 | Lo Curto et al. (2006); Mugrauer & Neuhäuser (2009) |
| □    | HD 27442 A | 1 | 1.28 | 1.18 | 238.4 | Butler et al. (2001); Chauvin et al. (2006) |
| □    | HD 28254 A | 1 | 1.16 | 2.25 | 241.7 | Raghavan et al. (2006); Mugrauer et al. (2007a) |
| □    | HD 14729 A | 1 | 0.82 | 2.08 | 283.5 | Naef et al. (2010) |
| □    | HD 46375 A | 1 | 0.25 | 0.04 | 345.7 | Butler et al. (2003); Mugrauer et al. (2005) |
| □    | WASP-8 A | 1 | 2.25 (true mass) | 0.08 | 348.0 | Marcy et al. (2000); Mugrauer et al. (2006a) |
| □    | WASP-8 B | 1 | 0.20 | 0.28 | 478.4 | Queloz et al. (2010) |
| □, ※ | HD 3651 A | 1 | 0.20 | 0.28 | 478.4 | Fischer et al. (2003a); Mugrauer et al. (2006b) |
| □    | HD 109749 A | 1 | 0.28 | 0.06 | 495.6 | Fischer et al. (2006); Desidera & Barbieri (2007) |
| □    | HD 99492 | 1 | 0.11 | 0.12 | 589.4 | Marcy et al. (2005b); Raghavan et al. (2006) |
| □    | HD 99491 B | 1 | 0.42 | 0.05 | 621.4 | Udry et al. (2000); Mugrauer et al. (2004a) |
| □    | HD 75289 A | 1 | 1.26 | 1.19 | 676.0 | Marcy et al. (2005b); Raghavan et al. (2006) |
| □    | HD 188015 A | 1 | 0.69…11.6 | 0.06…2.55 | 742.5 | Butler et al. (1999); Lowrance et al. (2002) |
| □    | GJ 766 A | 1 | 4.9 | 1.82 | 788.9 | Forveille et al. (2011) |
| □    | HD 137388 A | 1 | 0.22 | 0.89 | 809.4 | Dumusque et al. (2011) |
| □    | HD 142022 A | 1 | 4.40 | 2.80 | 890.8 | Eggenberger et al. (2006); Raghavan et al. (2006) |
| □    | 11 Com A | 1 | 19.4 | 1.29 | 999.0 | Liu et al. (2008) |
Table A.5. Extrasolar planets detected with transit or RV observations in wider binaries with a projected stellar separation of $\rho^\ast_{\text{proj}} > 1000 \text{ AU}$, sorted by an increasing stellar separation. If RV and transit measurements are available the true mass of the exoplanet candidate is given in the table.

New system compared to the latest published overview by Mugrauer & Neuhäuser (2009).
Closer component listed in the CCDM (formerly called B) was disproved by proper motion measurements, but a new wide stellar companion was found and confirmed by common proper motion (Mugrauer et al. 2005).
B component is a white dwarf, see Porto de Mello & da Silva (1997).

| Note | Host star | $N_{p_1}$ | $M_{p_1} \sin i$ [M$_\odot$] | $a_{p_1}$ [AU] | $\rho^\ast_{\text{proj}}$ [AU] | Reference |
|------|-----------|------------|-----------------|-------------|----------------|-----------|
| 1    | HD 11964 A | 2          | 0.11 and 0.61   | 0.25 and 3.34  | 1044         | Butler et al. (2006); Raghavan et al. (2006) |
|      | 55 Cnc A   | 5          | 0.02...3.84     | 0.04...5.77   | 1053         | Butler et al. (1997); Marcy et al. (2002); McArthur et al. (2004) |
|      | HD 80606 A | 1          | 3.94 (true mass) | 0.45         | 1197         | Naef et al. (2001a); Moutou et al. (2009) |
| ²    | HD 204941 A | 1          | 0.27            | 2.56         | 1447         | Dumusque et al. (2011) |
|      | HAT-P-1 B  | 1          | 0.52 (true mass) | 0.06         | 1557         | Bakos et al. (2007) |
| ³    | HD 101930 A | 1          | 0.30            | 0.30         | 2227         | Lovis et al. (2005); Mugrauer et al. (2007b) |
|      | HD 7449 A  | 2          | 1.11 and 2.00   | 2.30 and 4.96 | 2348         | Dumusque et al. (2011) |
| ⁴    | HD 89744 A | 2          | 7.99            | 0.89         | 2457         | Korzennik et al. (2000); Mugrauer et al. (2004b) |
| ⁵    | HD 190360 A | 2          | 0.06 and 1.50   | 0.13 and 3.92 | 3293         | Naef et al. (2003); Vogt et al. (2005); Raghavan et al. (2006) |
| ⁶    | HD 213240 A | 1          | 4.50            | 2.03         | 3905         | Santos et al. (2001); Mugrauer et al. (2005) |
| ⁷    | HD 147513 A | 1          | 1.00            | 1.26         | 4460         | Mayor et al. (2004); Mugrauer & Neuhäuser (2005) |
| ⁸    | HD 222582 A | 1          | 7.75            | 1.35         | 4595         | Vogt et al. (2000); Raghavan et al. (2006) |
| ⁹    | XO-2 A     | 1          | 0.57 (true mass) | 0.04         | 4619         | Burke et al. (2007) |
| ¹⁰   | HD 125612 A | 3          | 0.06...7.2      | 0.05...4.2   | 4752         | Fischer et al. (2007); Lo Curto et al. (2010) |
| ¹¹   | HD 20782 A | 1          | 1.90            | 1.38         | 9133         | Jones et al. (2006); Desidera & Barbieri (2007) |
| ¹²   | HD 38529 A | 2          | 0.78 and 17.70  | 0.13 and 3.69 | 11915         | Fischer et al. (2001, 2003b); Raghavan et al. (2006) |

Table A.6. Extrasolar planets detected with transit or RV observations in stellar systems with more than two components, sorted by the increasing projected separation of the host star and the nearest stellar component ($\rho^\ast_{\text{proj}}$). For the closest systems a value for the binary semi-major axis ($a_{\text{proj}}$) is known from multi-epoch observations (listed in brackets in the $\rho^\ast_{\text{proj}}$ column). If RV and transit measurements are available the true mass of the exoplanet candidate is given in the table.

New system compared to the latest published overview by Mugrauer & Neuhäuser (2009).

| Note | Host-star | $N_{p_1}$ | $N_\ast$ | $M_{p_1} \sin i$ [M$_\odot$] | $a_{p_1}$ [AU] | $\rho^\ast_{\text{proj}}$ [AU] | Reference |
|------|-----------|------------|----------|-----------------|-------------|----------------|-----------|
| ²    | HD 126114 A | 1          | 3        | 0.38            | 2.35         | 36.2           | Howard et al. (2010); Ginski et al. (2012) |
|      | HD 19994 A | 1          | 3        | 1.68            | 1.42         | 51.5           | Mayor et al. (2004); Raghavan et al. (2006) |
|      |           |            |          |                 |              |                | Roell et al. (2011) |
| ³    | GJ 667 C   | 2          | 3        | 0.018 and 0.014 | 0.05 and 0.12 | 227.0         | Anglada-Escudé et al. (2012) |
|      | HD 65216 A | 1          | 3        | 1.21            | 1.37         | 256.3         | Mayor et al. (2004); Mugrauer et al. (2007b) |
|      | HD 132563 B | 1          | 3        | 1.49            | 2.62         | 365.2         | Desidera et al. (2011) |
|      | HD 196050 A | 1          | 3        | 3.00            | 2.50         | 511.2         | Jones et al. (2002); Mugrauer et al. (2005) |
|      |           |            |          |                 |              |                | Eggenberger et al. (2007) |
| ⁴    | HD 178911 B | 1          | 3        | 6.29            | 0.32         | 794.3         | Zucker et al. (2002); Eggenberger et al. (2003) |
|      | 16 CyG B   | 1          | 3        | 1.68            | 1.68         | 859.7         | Cochran et al. (1997); Raghavan et al. (2006) |
|      | 30 Ari B   | 1          | 3        | 9.88            | 0.995        | 1517          | Guenther et al. (2009) |
| ⁵    | HD 40979 A | 1          | 3        | 3.32            | 0.81         | 6395          | Fischer et al. (2003b); Eggenberger et al. (2003) |
|      |           |            |          |                 |              |                | Mugrauer et al. (2007a) |