New Binaries in the ε Cha Association*

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Abstract

We present Adaptive Optics-aided speckle observations of 47 young stars in the ε Cha association made at the 4 m Southern Astrophysical Research Telescope in the H-band. We resolved 10 new binary pairs, 5 previously known binaries, and 2 triple systems, also previously known. In the separation range between 4 and 300 au, the 30 association members of spectral types G0 and later host 6 binary companions, leading to the raw companion frequency of 0.010 ± 0.004 per decade of separation, comparable to the main sequence dwarfs in the field. On the other hand, all five massive association members of spectral types A and B have companions in this range. We discuss the newly resolved and known binaries in our sample. Observed motions in the triple system ε Cha, composed of three similar B9V stars, can be described by tentative orbits with periods 13 and ~900 years and a large mutual inclination.

Key words: binaries: close – open clusters and associations: individual (epsilon Cha) – stars: pre-main sequence – techniques: high angular resolution

Supporting material: machine-readable tables

1. Introduction

Multiple star systems are a common product of the process of star formation (Duchêne & Kraus 2013). Characterizing stellar multiplicity in young stellar populations is therefore an important and necessary step toward understanding issues like the fragmentation of primordial cores or massive disks, the early dynamical evolution of stellar systems, the initial mass function of single stars versus multiples, and how stellar multiplicity affects the survival and evolution of circumstellar disks, which bears ultimately on the frequency and properties of planets orbiting binary and multiple star systems (see, e.g., review by Reipurth et al. 2014).

Over the past decades we have learned that loose associations like Taurus and Chamaeleon I harbor roughly twice as many low-mass (M ≤ 2 M⊙) pre-main sequence binaries as compact clusters of a similar age, like the Orion Nebula Cluster, which have multiplicity fractions similar to the field (e.g., Petr et al. 1998; Köhler et al. 2006). These observations can be interpreted with the assumption of a universally high (~100%) primordial multiplicity fraction for all star-forming regions, with the subsequent rapid dynamical disruption of binaries in young dense clusters, which significantly lowers the multiplicity fractions (Kroupa 1995; Kroupa et al. 1999; Kroupa & Petr-Gotzens 2011). However, the universality of a high primordial multiplicity fraction, independent of the star-forming environment, has lately been questioned and remains debated (King et al. 2012; Marks et al. 2014). Parker & Meyer (2014) find that dynamical processing of populations composed of 100% binaries, even in dense star-forming regions, cannot explain the clear differences in the Galactic field binary fraction and mean separation as a function of decreasing primary mass. In summary, there is accumulating evidence that the primordial binary frequency and separation distribution are not universal, but may depend on the star-forming environment. Therefore, it is important to measure multiplicity properties of many young clusters and associations. This work focuses on one such group.

Because of their proximity, the so-called nearby young moving groups (Zuckerman & Song 2004; Torres et al. 2008), like the η Cha cluster (Mamajek et al. 1999) and ε Cha association, are excellent laboratories to investigate stellar multiplicity over a wide range of separations. These two stellar aggregates were first proposed by Frink et al. (1998) as a kinematic group of young stars in the general direction of the Chamaeleon dark clouds. Mamajek et al. (2000) discuss ε Cha as a sparse association in the context of other nearby stellar systems, and characterize it as a distinct group of 5–15 Myr old stars. Feigelson et al. (2003) derived an age of 3–5 Myr for ε Cha. Several recent studies have concentrated on building better membership lists. In their re-examination of the ε Cha group membership, Murphy et al. (2013) arrive at a final list of 35–41 members, with a mean distance of 110 ± 7 pc and an age ~3–5 Myr, making it likely the youngest of the nearby moving groups. This is the most complete census of the association available to date; for comparison, Elliott et al. (2015) listed only 24 members of ε Cha (17 of them are found in Murphy et al. 2013). Note that attribution of a star to a particular association is complicated because of the partial overlap between young groups; binarity adds yet another complication by distorting photometry and proper motions.

Multiplicity of young stars has been extensively characterized observationally, mostly by high angular resolution imaging (see the review in Duchêne & Kraus 2013). However, ε Cha has been largely neglected so far by these studies. The most extensive data are provided by Köhler (2001) who observed X-ray selected young stars in the direction of the dark clouds in Chamaeleon, resolving binaries with separations from 0″13 to 6″. He made no distinction between the more distant Cha I and Cha II groups and the foreground ε Cha association; 18 objects of his study overlap with our sample. Köhler found the multiplicity fraction to be comparable to the field. Recently, Elliott et al. (2015) probed binarity in ε Cha by high-resolution imaging of 10 targets, detecting three binaries. One of those,
RX J1220.4-7407 (KOH 93), was first resolved by Köhler, TYC 9245-535-1 is not featured in our input list, while HD 105923 is independently confirmed by our survey.

Here, we present a study of multiplicity of 47 young stars in the direction of the ε Cha stellar group; 37 of those are confirmed or candidate members of the association. This is the most extensive search to date for binaries and multiple systems in ε Cha, in the separation range ~0′′04–3′′ (equivalent to projected separations ~4–300 au, assuming a mean distance of 100 pc). In Section 2, we present the observations, and in Section 4 we present our results. Section 3 discusses the multiplicity in ε Cha and concludes the paper.

2. Observations

2.1. Sample Selection

For the target selection, we used the list of proposed members of the ε Cha association from the Table 1 of Murphy et al. (2013). Here, in Table 1 we provide the characteristics of the 47 observed stars. The members confirmed by Murphy et al. (2013) have their corresponding Cha-NN numbers in column (2); candidate members are marked as Cha-cand, while the rejected members are labeled as Cha-rej. Columns (2) and (3) contain the star position, columns (5) and (6) denote the \(I\) magnitude and Spectral Type respectively, and in columns (7) and (8), we provide distances derived from the \(\text{Gaia} DR1\) parallaxes (Gaia Collaboration et al. 2016a), and from Murphy et al. (2013). Two candidates, TYC 9414-191-1 and TYC 9420-676-1, can be rejected based on their \(\text{Gaia}\) parallaxes (Lindegren et al. 2016), so their status is set accordingly. On the other hand, HIP 55746 has a \(\text{Gaia}\) parallax of 10.74 mas and is most likely a member of the association; its rejection by Murphy et al. (2013) could have been caused by its close binary companion. For previously known multiples listed in the Washington Double Star (WDS) Catalog (Mason et al. 2001), the “discoverer codes” are given in column (2). The separations in column (9) of Table 1 indicate which objects have been resolved; asterisks mark first-time resolutions. Three stars from the original list, 2MJ11334926-7618399, 2MJ11404967-7459394, and 2MJ12014343-7835472, all fainter than \(I = 14.1\), were not observed and therefore are not included in Table 1.

The final list contains 37 ε Cha members/candidates among the 47 entries in Table 1. However, it should be pointed out that the 10 rejected stars are, for the most part, young objects. Their attribution to a particular association or group might be compromised by multiplicity. We believe that their observations are useful regardless of the membership status. Monitoring of known close young binaries will establish their orbits and masses (e.g., EG Cha, Tokovinin 2016).

2.2. Instrument and Observing Method

The speckle observations reported here were obtained on 2016 January 17. The time was allocated through the NOAO program 2015B-0268, C. Briceño Principal Investigator. The sky was clear, with good seeing and a slow wind.

We used the High-Resolution Camera (HRCam)—a fast imager designed to work at the 4.1 m SOAR telescope (Tokovinin & Cantarutti 2008). The camera was mounted on the SOAR Adaptive Optics Module (SAM; Tokovinin et al. 2016a). We used the UV laser to correct for turbulence in order to achieve a deeper magnitude limit and better resolution; this observing mode was used earlier for screening Kepler-2 variable stars for companions (Schmitt et al. 2016). The SAM module corrects for atmospheric dispersion and helps to calibrate the pixel scale and orientation of HRCam (see Tokovinin et al. 2015). We used mostly the \(I\)-band filter (\(\lambda_0 = 788\) nm; FWHM = 132 nm). The transmission curves of HRCam filters are given in the instrument manual.

After acquiring each target and centering it in the HRCam field, we closed the laser loop. The overhead associated with using the laser guide star (LGS) was only a few seconds when observing multiple targets in the same area of the sky. Once the LGS is centered for one target, no further adjustments are needed for the following targets. The laser switches on when the telescope is slewed to the target (the software that controls laser propagation within authorized time windows takes care of this). Laser interrupts had only a minor effect because the exposure times were short. The high-order AO loop compensates for telescope aberrations and low-altitude turbulence; it automatically maintains the optimum focus. Residual tip and tilt jitter is compensated in the data processing. If we had used a classical CCD imager, also available with SAM, the observations would have been much less efficient because acquisition of off-axis guide stars would be needed for each field. For example, the binary survey using SAM with a classical CCD could cover only 21 targets in one night (Tokovinin 2014); in contrast, the 47 stars of this program were observed in 3.2 hr.

Without the laser, HRCam reaches a magnitude limit of \(I \sim 12\) mag under good seeing. SAM provides an increase of ~3 magnitudes in depth, allowing us to go down to \(I \sim 13\) mag targets (Table 1). We used a detector binning of \(2 \times 2\) that produces an effective pixel scale of 30.46 mas. For each target, we acquired two cubes of \(200^0\) binned pixels size, covering the field of \(6^\circ \times 6^\circ\), with 400 frames per cube. The exposure time was from 0.1 to 0.2 s per frame, depending on the target brightness (i.e., 40–80 s accumulation time per data cube). Then two more cubes were acquired with half the field and a shorter exposure (typically 0.05–0.1 s). These extra narrow-field cubes helped to increase the resolution at the expense of sensitivity. Shorter exposures were used for targets brighter than \(I = 12\) mag, which were also recorded without binning. Bright stars did not need the laser correction. Acquisition of two data cubes in each mode helps to confirm new detections and avoids artifacts, such as occasional cosmic rays spoiling some frames in one of the two cubes.

During these observations, the seeing in the free atmosphere reported by the site monitor was very good, fluctuating around 0′′3. The total seeing varied between 0′′5 and 1′′. The SAM AO system successfully compensated low-altitude turbulence and delivered sharp images. The median Full Width at Half Maximum (FWHM) of the re-centered average images in the closed loop is 0′′33, while some data cubes have FWHM less than 0′′25 and 80% are better than 0′′4.

Some newly resolved pairs have been re-observed with HRCam on 2017 May 15, this time without the laser and under mediocre seeing. These confirmation measurements prove that even relatively faint companions at ~1″ separation are not background stars. Otherwise, the relatively large proper motion of 40 mas yr\(^{-1}\), directed to the West, would have changed the

\(^1\) http://www.ctio.noao.edu/soar/content/soar-adaptive-optics-module-sam

\(^2\) http://www.ctio.noao.edu/~atokovin/speckle/index.html
relative companion positions by 0°05, significantly larger than the errors.

2.3. Data Processing

The speckle data processing described in (Tokovinin et al. 2010, hereafter TMH10) was adapted to the faint stars (see Schmitt et al. 2016). It is illustrated in Figure 1. As a first step, power spectra are calculated from the data cubes. While processing each frame, the bias and scaled dark signals are subtracted. The auto-correlation functions (ACFs) are computed from the power spectra. They are used to detect companions and to evaluate the detection limits. For each data cube, the speckle pipeline also delivers the average image re-
For closer pairs, the separation is 1.75 mag, while the diffraction-limited resolution of 0.04 was in column 2 equals the diffraction limit while the dotted lines represent the individual limits.

The detection limits were estimated from the ACFs by computing the variance in annular zones and assuming that companions brighter than 5σ are detectable (see TMH10). Figure 2 shows the detection limits for faint targets observed in closed loop. They vary substantially, depending on the target brightness and AO compensation quality. The median magnitude difference ∆I at 0″15 separation is 1.75 mag, while at 1″ separation, it reaches 4 mag. Individual ∆I limits at these two characteristic separations are provided in Table 3 for unresolved targets. Linear interpolation between these points can be used to get the detection limits at other separations.

Figure 3 shows centered or SAA images of six newly resolved binaries. Another three new close pairs are illustrated in Figure 4 by their power spectra showing fringes or elongation.

Table 2 lists 31 measures of 20 binary pairs, including 10 newly resolved ones. The columns of Table 2 contain (1) the WDS-style code based on the J2000 coordinates, (2) the star name, from Table 1 in Murphy et al. (2013), (3) the Besselian epoch of observation, (4) the filter used, (5) the position angle θ in degrees, (6) the separation ρ in arcseconds, (7) the magnitude difference ∆m, with an asterisk following it if ∆m and the true quadrant are determined from the resolved long-exposure image; a colon indicates that the data are noisy and ∆m is likely overestimated (see TMH10 for details); the flag “q” means that the quadrant is determined from the SAA image. In cases of multiple stars, the positions and photometry refer to the pairings between individual stars, not the photocenters of subsystems. The last column (8), gives short notes for some objects.

Overall, we measured eight known systems (including three triples, of which we confirmed two) and added ten new binary pairs resolved here for the first time. Section 3.1 gives comments on individual binaries, Section 3.2 is devoted to the multiple system ε Cha itself.

3.1. Comments on Resolved Systems in ε Cha

11080-7742. VW Cha (GHE 35 AB) is a K7-M0 accreting Classical T Tauri star, classified as a Class II object based on its Spectral Energy Distribution (SED; Manoj et al. 2011). This system is resolved at 0″66, without any trace of the 0″1 subsystem BNK 1 Ba,Bb discovered by Brandeker et al. (2001)
in 2000. The subsystem Ba,Bb was also unresolved at SOAR in 2014 and 2015, although at \( D_J = 0.3 \) mag it should be easily detectable. It is possible that the pair Ba,Bb became closer (its estimated period is \( \sim 70 \) years). The pair AB moved very little since its discovery in 1994; its estimated period is \( \sim 400 \) years. It is not a member of the association, but definitely a young object; Murphy et al. (2013) attribute it to the Cha I group. It is not featured in the \textit{Gaia} DR1, so its true membership is still difficult to ascertain.

11186-7936. 2MASS J11183572-7935548 (Cha 13, \( I = 12.22 \) mag, M4.5) is a new 0.92 binary. Murphy et al. (2013) suspected RV variability, which might mean that it is triple, because the new wide pair has a period of \( \sim 2 \) kyr. In their \textit{Spitzer} study of Chamaeleon, Manoj et al. (2011) classify this star as a Weak-lined T Tauri star based on the modest H\( \alpha \) emission equivalent width of 11 \( \text{Å} \) reported in literature low resolution spectra. However, the SED clearly shows this is not a disk-less star, quite the contrary. Though it has a stellar-like SED out to \( \sim 3 \mu \text{m} \), it exhibits significant excess emission at longer wavelengths, with a strong 10 \( \mu \text{m} \) silicate emission feature, indicative of a small amount of optically thin dust in an otherwise cleared gap; thus, they classify it as a candidate Transitional Disk (TD). Murphy et al. (2013) also find that H\( \alpha \) is variable in Cha-13, though the line profile itself is not very wide, with a 10% width of \( \sim 170 \) km s\(^{-1} \), consistent with a low accretion rate of \( \sim 10^{-11} \) \( M_T \) yr\(^{-1} \). These characteristics closely resemble those of other TDs, like CVSO-224 in Orion (Espaillat et al. 2008). In addition to H\( \alpha \), Murphy et al. (2013) find a number of other emission lines in their spectra of Cha-13, like HeI, [N II]\( \lambda \)6548/6583, [S II]\( \lambda \)6716/6731, among others, leading them to suggest the gap may have been cleared by jet/outflow activity. Our discovery of a companion at \( \sim 90 \) au raises the alternative interpretation that the TD status is related to the binary nature of the system. At separations of \( \lesssim 200 \) au, a companion can truncate the outer disk, while at separations of \( \lesssim \) few tens of au, the disk could be truncated from the inside (Manoj et al. 2011). Indeed, studying Chamaeleon I, Daemgen et al. (2016) find that there is a statistically significant difference in the accretor fraction between single and binary systems; in particular, binary systems with separations \( \lesssim 100 \) au show a low \( \sim 6\% \) incidence of accretion activity. More specifically, a recent study of 24 TDs shows that close to 38% can be explained by tidal interactions between a close binary companion and its disk, while the remaining proportion are likely the result of processes like disk photoevaporation, grain growth, or planet–disk interactions (Ruíz-Rodríguez et al. 2016). Does the weak accretion activity and excess infrared emission in Cha-13 originate in one or two circumprimary disks, or maybe in a circumbinary disk? Has the gap in this TD system been carved out by the binary companion? These are open questions for this very interesting system, which clearly deserves further detailed studies.

11253-8457. HIP 55746 is revealed as a tight 60 mas binary with an estimated period of \( \sim 10 \) years. This close pair was suspected from the astrometric acceleration detected by
The pair was resolved again at SOAR in 2016.96 and closed down to about 30 mas in 2017.34 (the elongated power spectrum was not fitted, no measurement). There is another companion at $3^\circ54$ (RST 2752), so the system is triple. The wide physical companion, last seen in 1996 at ($208^\circ$, $37^\circ$), is outside the field of view, hence it is not detected here.

$11375-7648$. RX J1137.4-7648 ($I = 12.2$ mag, M2), not a member of $\epsilon$ Cha, has a wide 2″9 companion that just fits in the 6″ field. Its image is partially truncated, so the $\Delta I$ is overestimated by some unknown amount. Although Murphy et al. (2013) call it “equal-brightness visual binary,” and it is evident as a visual pair in Digitized Sky Survey (DSS) and 2 Micron All-Sky Survey (2MASS) images, this pair is not featured neither in the literature nor in the WDS.

$11415-7347$. TYC 9238-612-1 ($I = 9.98$ mag, G5) has a faint companion at 2″28. It is barely detectable at the same position in 2017.37, confirming that the companion is physical. The new companion is too distant for explaining the RV variability suspected by Murphy et al. (2013).

$11509-7411$. RX J11509.9-7411; BRR 15, resolved here at 0″91. It has not moved appreciably since its discovery in 1994. Köhler (2001) found it at 0″875 and 106″7.

$11585-7749$. HD 104036 ($I = 6.49$ mag, A7) has a new faint companion at 0″63. The pair is found at the same position in 2017.37, confirming that the companion is physical. The new companion is too distant for explaining the RV variability suspected by Murphy et al. (2013).

The WDS component F corresponds to the “star 2” in Grady et al. (2004) and is sometimes called “B,” causing confusion with the 4″ pair FGL 2AB listed in the WDS, which is erroneous and unphysical. Based on the images presented by Grady et al. (2004) and Feigelson et al. (2003), the close AF pair is the same as the AB pair described by Feigelson et al. (2003), and there is no 4″ pair among the known components. The WDS AB pair appears to be a historical artifact.

Note. Values marked with an asterisk (*) indicate objects for which the magnitude difference $\Delta m$ and the true quadrant were determined from the resolved long-exposure image.

(This table is available in machine-readable form.)
C, although the orbital period of such a wide pair AB.C would be on the order of 0.5 Myr. The 19 day inner spectroscopic binary resolved interferometrically by García et al. (2013) has a semimajor axis of 2 mas, well below the SOAR resolution limit. Not surprisingly, our observations do not reveal any additional close companions to HD 104237 itself and to two of its satellites because these objects are already well studied.

1201-7853. RX J1201.7-7853 (i = 10.5 mag, M0) has an elongated power spectrum corresponding to a 50 mas binary (Figure 4). The resolution is tentative, but likely real by comparison with other targets that do not show similar elongation. This star was observed by Köhler (2001) but not resolved, being below the diffraction limit of 0.13. The RV variability found by Murphy et al. (2013) could be caused by the new close companion.

12049-7932. TYC 9420-676-1 (i = 9.7 mag, F0) has a new companion at 0.65 arcsec, confirmed as physical by its repeated measurement in 2017.37. According to Murphy et al. (2013), it does not belong to the association.

12070-7844. HD 105234 (i = 7.2 mag, A9) has a new 1.44 arcsec companion, confirmed as physical in 2017.37.

12091-7846. HIP 59243 (i = 6.56 mag, A6) is resolved at 1.57 arcsec. The binary is very likely physical, but there is no second measure to confirm this.

12116-7110. HD 105923 (i = 8.3 mag, G0) has a faint companion at 1.99 arcsec. Elliott et al. (2015) also detected this binary in 2006 at 1.96 and 145.71. The companion is thus physical.

12204-7407. RX J1220.4-7407 (i = 10.80 mag, M0) is a known binary KOH 93. It was discovered in 1996 at (348.4, 0.296) by Köhler (2001). It is found here at (9°3, 0°24). The estimated period is ~140 years; the observed direct motion (21° in 30 years) matches this crude estimate. According to Murphy et al. (2013), the star RX J1219.77403 at a projected separation of 0.14 pc could be bound to this binary, thus making it triple system.

12431-7459. RX J1243.1-7458 (i = 12.72 mag, M3.2), not a member of ε Cha, is resolved as a triple system consisting of the close 0.23 arcsec pair and a fainter companion at 2.5′. This triple is already known, designated in the WDS as KOH 94 Aa,Ab and BRR 6 AB. The inner subsystem was discovered in 1996 at (85°, 0°3) (Köhler 2001) and not measured since. It is found at (78°3, 0°23). The orbital motion is slow. Murphy et al. (2013) note a possible spectroscopic companion, which, if true, would make this a quadruple system. They assign this system to the more distant Cha II cloud population.

### Table 3: Detection Limits for Unresolved Targets

| Name            | $\rho_{\text{lim}}$ (″) | $\Delta m(0.15)$ (mag) | $\Delta m(1.0)$ (mag) |
|-----------------|------------------------|-----------------------|----------------------|
| HD 82879        | 0.04                   | 1.6                   | 5.1                  |
| CP-68 1388      | 0.04                   | 2.2                   | 4.8                  |
| TYC 9414-191-1  | 0.04                   | 1.6                   | 4.3                  |
| RX J1123.2-7924 | 0.04                   | 1.9                   | 3.4                  |
| 2MJ11432669-78...| 0.10                   | 0.9                   | 2.2                  |
| RX J1147.7-7842 | 0.04                   | 1.7                   | 4.0                  |
| RX J1149.8-7850 | 0.04                   | 2.1                   | 4.3                  |
| RX J1150.4-7704 | 0.04                   | 1.8                   | 4.6                  |
| 2MJ11550485-79...| 0.10                   | 1.7                   | 3.3                  |
| T Cha           | 0.04                   | 2.4                   | 5.1                  |
| RX J1158.5-7754B| 0.04                   | 2.0                   | 4.2                  |
| CXOUJ115908     | 0.10                   | 2.2                   | 2.3                  |
| HD 104237E      | 0.04                   | 1.6                   | 4.6                  |
| 2MJ12005517-78...| 0.04                   | 1.4                   | 2.6                  |
| HD 104467       | 0.04                   | 0.7                   | 6.1                  |
| USN0B-130144-78...| 0.10                   | 2.0                   | 2.9                  |
| CXOUJ120152-78...| 0.10                   | 2.0                   | 3.2                  |
| RX J1202.7-7718 | 0.04                   | 2.5                   | 4.5                  |
| RX J1204.6-7731 | 0.04                   | 2.3                   | 4.5                  |
| 2MJ12074597     | 0.10                   | 2.5                   | 3.6                  |
| RX J1207.7-7953 | 0.04                   | 2.6                   | 3.9                  |
| RX J1216.8-7753 | 0.04                   | 2.4                   | 4.6                  |
| RX J1219.7-7403 | 0.04                   | 1.8                   | 4.2                  |
| 2MJ12210499-71...| 0.04                   | 1.7                   | 5.1                  |
| RX J1239.4-7502 | 0.04                   | 1.9                   | 5.3                  |
| CD-69 1055      | 0.04                   | 0.7                   | 5.2                  |
| CM Cha          | 0.04                   | 2.2                   | 4.4                  |
| MP Mus          | 0.04                   | 2.1                   | 4.9                  |

(This table is available in machine-readable form.)

The central star of the association, ε Cha (HIP 58474, HD 104174, B9V), is a known binary, discovered in 1835 by Herschel (1847) at a separation of 1°6 and position angle 179°. Since the discovery, the separation of the bright companion B has steadily decreased to the present 0.17, with a slow increase of the position angle to 240°. In 2015, the system was observed at SOAR and unexpectedly resolved into a tight triple with nearly equal components (Tokovinin et al. 2016b).

The inner 50 mas pair has turned by 29° in two years since its discovery, in agreement with its estimated short period. Figure 5 shows the tentative orbits of the outer and inner pairs computed from the available data. These orbits, still quite uncertain, are given here only as an illustration; they are not yet ready for publication. The provisional orbits match the expected masses of these stars, about 2.5 $M_\odot$ each. The short inner period means that the inner orbit will be constrained in a

![Figure 5](image-url)

The tentative orbits of the triple system ε Cha with axis scale in arcseconds. Only a fragment of the outer orbit is plotted; its wavy trajectory reflects the wobble caused by the inner subsystem. Crosses and squares connect to the orbit by dotted lines denote the measurements of the outer pair, with some dates indicated (the first measurement made in 1835 is outside the plot). Triangles mark the measurements of the inner pair. The insert shows the ACF recorded at SOAR on 2017 May 15 where Ab and B mark the peaks corresponding to the two companions.

### 3.2. The Triple System ε Cha

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few more years, while the millennium-long outer orbit will remain uncertain due to the lack of coverage. Accurate speckle measurements at SOAR begin to show the “wobble” in the relative position of Aa and Ab caused by the subsystem. The amplitude of the wobble is about half of the inner semimajor axis because the components Aa and Ab have comparable masses. Future monitoring of this interesting triple system will allow accurate measurements of the masses of these young B9V stars and will provide a valuable anchor point for stellar evolutionary models.

Interestingly, the inner and outer pairs in ε Cha rotate in opposite directions. The provisional orbits are almost orthogonal, while the inner orbit has a large eccentricity of ~0.8. This triple system may be undergoing Lidov–Kozai cycles that might lead to the formation of a close inner binary (see the review by Naoz 2016).

4. Discussion: The Multiplicity Fraction

The multiplicity strongly depends on the mass (Duchêne & Kraus 2013). To be meaningful, the observationally determined multiplicity fraction must refer to the well-defined range of primary masses, separations (or periods), and mass ratios. However, masses and mass ratios are notoriously difficult to estimate for PMS stars. As the small sample size does not allow accurate multiplicity measurement in ε Cha, crude qualitative estimates of the multiplicity fraction given below seem to be appropriate. Owing to the limited observational material, we prefer not to speculate about the multiplicity statistics in ε Cha or compare with other young groups.

We select from Table 1 30 members and candidate members of ε Cha with spectral types of G0 or later (I > 8 mag) for comparison with the field dwarfs. There are 6 binaries in the projected separation range from 4 to 300 au (1.9 dex). All of those companions are physical. This leads to a raw multiplicity fraction of 0.10 ± 0.04 per decade of separation. As we have not sampled the full range of mass ratios owing to the separation-dependent detection limit, the actual multiplicity fraction is higher, but this correction depends on the mass ratio distribution and is highly uncertain. Within errors, the multiplicity of low-mass stars in ε Cha appears to be comparable to the multiplicity fraction of solar-type dwarfs in this separation range, about 0.15 per decade (Duchêne & Kraus 2013).

We have not detected any companions to the four targets fainter than I = 13 mag. However, the detection limits for faint stars are not very deep, while the number of those low-mass members is too small to make any conclusions regarding multiplicity dependence on mass. The faintest resolved association member, Cha-13, has I = 12.2 mag and spectral type M4.5.

Among the five massive association members with spectral types A and B (I < 8 mag), we find a total of six companions in the surveyed separation range (4–300 au), leading to the multiplicity fraction of 1.2 (0.6 per decade of separation). Four of those massive stars (HD 104036, HD 104237, HD 105234, and HIP 59243) have low-mass companions at separations larger than 60 au. Only ε Cha itself stands out, being composed of three nearly equal B9V stars.

Figure 6 plots separations of the binary association members on the logarithmic scale and compares them to the median detection limit from Figure 2. Several faint companions with separations of the order of 1″ are close to the limit and would have been missed if they were much closer. Interestingly, in Figure 3 of Köhler (2001), there are also several binaries with separations between 0″3 and 6″ and faint companions (flux ratios less than 0.3 in the K-band), as well as a distinct group of binaries with smaller separations and roughly equal components. There may be a similar pattern in Figure 6, where all close binaries have small ΔI. It would be interesting to probe the presence or absence of close and low-mass companions with a high-contrast AO, as our detection limits at small separations are not deep enough.

We cannot help noting that our relatively small sample contains five young triple systems (not all of them are association members). In summary, our work contributes new observational material on the binary statistics in young associations and clusters. The ε Cha association appears to be different in this respect from the neighboring η Cha cluster, where Becker et al. (2013) noted the lack of low-mass stars (a top-heavy IMF) as well as the absence of binaries with separations above 20 au.

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Facility: SOAR.
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