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A Speckle/AO Survey for Binaries in the η Cha Cluster

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Abstract. We report the results of a search for binary stars in the η Cha cluster. We find two close binaries (separation $\approx 0.2''$), but no wider binaries. If we use the correct positions of the binary components to draw the Hertzsprung-Russel diagram, the age spread of the cluster members is even smaller than before.

1. Introduction

The η Chamaeleontis cluster is a nearby compact group of pre-main-sequence (PMS) stars discovered recently. Due to its proximity ($d = 97$ pc), the lack of interstellar or circumstellar extinction, and the small spread of stellar ages, it is a sensitive tool for testing PMS evolutionary models. However, to correctly place the stars in Hertzsprung-Russel diagram, we have to know the luminosity of individual stars, not just the combined luminosity of a binary.

Furthermore, by comparing the distribution of separations to other star-forming regions, we can find out in which kind of environment the stars originally formed.

Finally, the closest binaries in η Cha resolvable today should have orbital periods of the order of 40 years. The determination of their orbits would give us their mass, which would provide another test for evolutionary models.

2. Observations

At the time this survey was carried out, 12 members of the η Cha cluster were known (Mamajek et al. 1999). Four of these stars had already been discovered in the ROSAT All-Sky Survey by Alcalá et al. (1996). These stars were observed in the course of a multiplicity survey of X-ray selected stars in Chamaeleon (Köhler 2001). We used speckle interferometry at the ESO New Technology Telescope (NTT) in March and April 1996, and direct imaging with the ESO/MPIA 2.2 m telescope in March 1996.

The remaining 8 stars were observed in May and June 2000 using the Adaptive Optics system ADONIS at the 3.6 m telescope on La Silla. All observations were carried out in the K-band at 2.2 μm.

The observations allow us to find companion stars with separations between $0.13''$ (the diffraction limit of a 3.6 m telescope) and about $9''$ (the field of view of the camera used with ADONIS). We can find binaries with a magnitude difference less than 2.5 mag.

3. Results

We found four companion stars, listed in Table 1. Since we have only one or two observations of each star, we cannot be sure if they are really in an orbit around the primary, or if they are background objects that happen to be near the target. To get an estimate for the number of chance projections, we use the results of our survey of stars in Chamaeleon (Köhler 2001). There we used the wide-field images obtained at the 2.2 m telescope to determine the field star density and obtained $(4.3 \pm 0.5) \cdot 10^{-4}$ stars per arcsec^2. For the 12 stars surveyed in η Cha, we expect about one chance projection within $8''$ separation, and two within $11''$. Therefore, the wide companions to RECX1 and RECX7 are most probably unrelated background stars.

Table 1. Binary and triple stars found in η Cha

Name		Date of Observation	Separation ["]	Position Angle [°]	Brightness Ratio at K
RECX1	A-B	29. Mar. 96	0.135±0.003	285.9±1.8	0.805±0.024
	A-B	29. May 00	0.180±0.003	93.1±0.3	0.901±0.014
	AB-C	29. Feb. 96	8.607±0.009	282.9±0.1	0.030±0.001
RECX7		26. Feb. 96	10.950±0.028	307.4±0.1	0.009±0.001
RECX9		5. June 00	0.210±0.006	104.6±1.4	0.48 ±0.155

3.1. RECX1

We observed RECX1 in 1996 and 2000 and find a significant change in the relative position. The position angle changed by 167° in 4 years and 2 months, which corresponds to an orbital period of about 9 years. Together with the semi-mayor axis of about 15 AU, Kepler's third law yields a system mass of 42 $M_\odot$, way too high for this system. However, the components are of nearly equal brightness. It is therefore conceivable that the stars exchanged the role of primary and secondary, which changes the position angle by 180°. The remaining difference can easily be explained by orbital motion in a system of about 1 $M_\odot$.

Unfortunately, two positions in the orbit are not enough to get even a rough estimate of the orbital parameters. Fig. 1 shows some possible solutions under the additional assumption that the orbit is circular and inclined against the line of sight, or elliptical and seen face-on. With a few more observations in the next years, it should be possible to restrict the orbital parameters and obtain a system mass precise enough to test evolutionary models.

3.2. The Separation Distribution

Figure 2 shows the distribution of separations of the binaries we found. The expected number of background stars in each histogram bin has been subtracted, thus only the two close binaries remain. The lack of companions around 100 AU is remarkable. These binaries are easy to find, and a significant fraction of main-sequence stars have companions at these separations.

Figure 2 also shows the binary distributions in the T association Taurus-Auriga and the young Orion Trapezium Cluster. The distribution in η Cha is

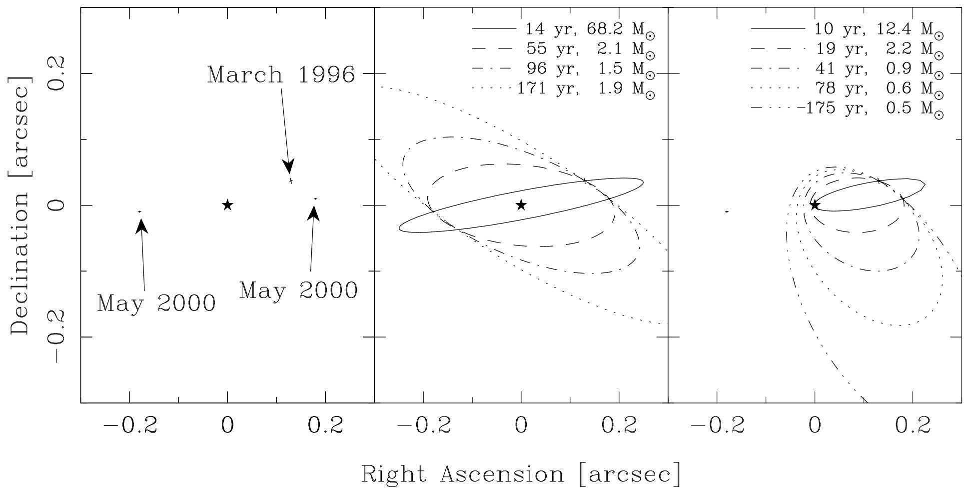

Figure 1. Left: the observed positions of RECX1. In 2000, we found the secondary at position angle 93°. However, if we assume that the fainter component in 1996 became the brighter one in 2000, the position angle would be 273°. Middle: A few circular orbits that match the two observed positions. The orbital periods and system masses are indicated in the figure. Right: Likewise, but for face-on elliptical orbits.

clearly different from that in Taurus, but similar to the distribution in Orion. The number of close binaries in Orion is comparable to main-sequence stars, but there are no binaries wider than 1000 AU. This can be explained by the disruption of binaries in stellar encounters (Kroupa et al. 1999).

The same mechanism could have caused the separation distribution in η Cha. However, it is not clear whether the stellar density in η Cha ever was high enough to destroy a large number of binaries. A better model might be the dynamical decay of few-body clusters (Sterzik, this volume).

Alternatively, the shape of the separation distribution might not be caused by the stellar density alone, but by other environmental effects, maybe related to the presence of high-mass stars (cf. Köhler et al. 2000).

4. The New HR Diagram

Lawson & Feigelson (2001) compared the late-type η Cha stars to four sets of PMS models. The models by Siess et al. (2000) give more self-consistent ages across the cluster than other models, but there are a few stars with luminosities higher than other cluster members of similar type. Figure 3 shows the Hertzsprung-Russel diagram after correction for the binaries found in our survey. Since we do not know the spectral energy distribution of the binary components, we assumed that the luminosity ratio is the same as the flux ratio in the K band. In the case of the equal-brightness binary RECX1, we can also assume that both components have the same effective temperature. In the case of RECX9, we adopt the observed temperature as the temperature of the pri-

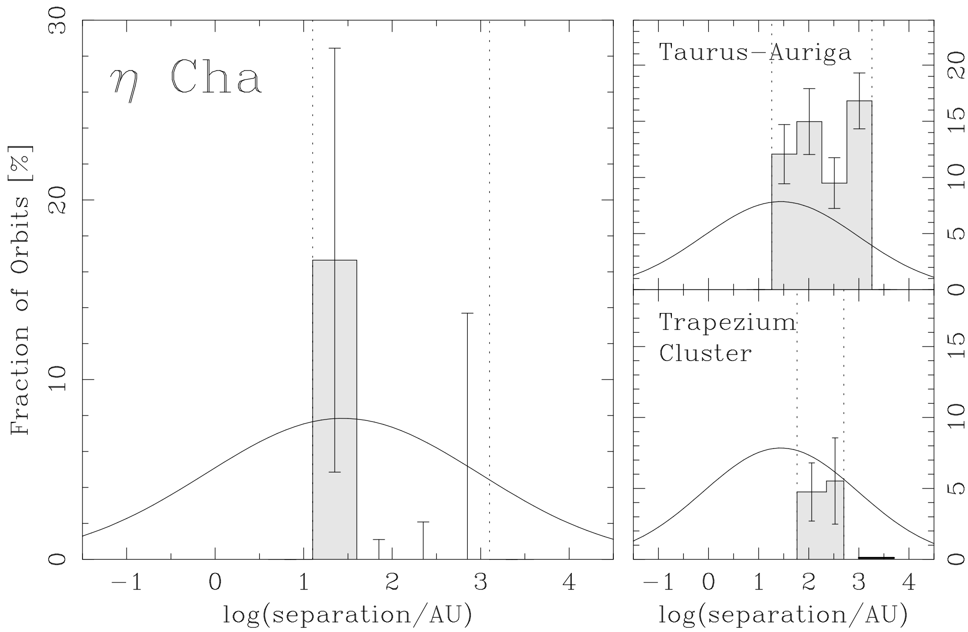

Figure 2. The separation distributions of binaries in η Cha (this work), Taurus-Auriga (Köhler & Leinert 1998), and the Orion Trapezium Cluster (Petr et al. 1998, Scally et al. 1999). The histograms show the results for young stars, the Gaussian-shaped curve those for solar-type main-sequence stars (Duquennoy & Mayor 1991). The dotted lines indicate the range of separations where the surveys were able to detect binaries. Scally et al. (1999) found no binaries in the Trapezium between 1000 and 5000 AU, which is indicated by the thick line.

mary. The secondary is probably cooler, but the available data does not allow to estimate its temperature.

With the luminosities corrected for binaries, the age spread is even smaller than before. The only exception is RECX12, which is brighter by a factor of about two. We re-examined our speckle data and find indications that it is a binary with a separation somewhat smaller than the diffraction limit. To fully resolve this star, we have to wait for the AO systems at the 8 m telescopes on the southern hemisphere.

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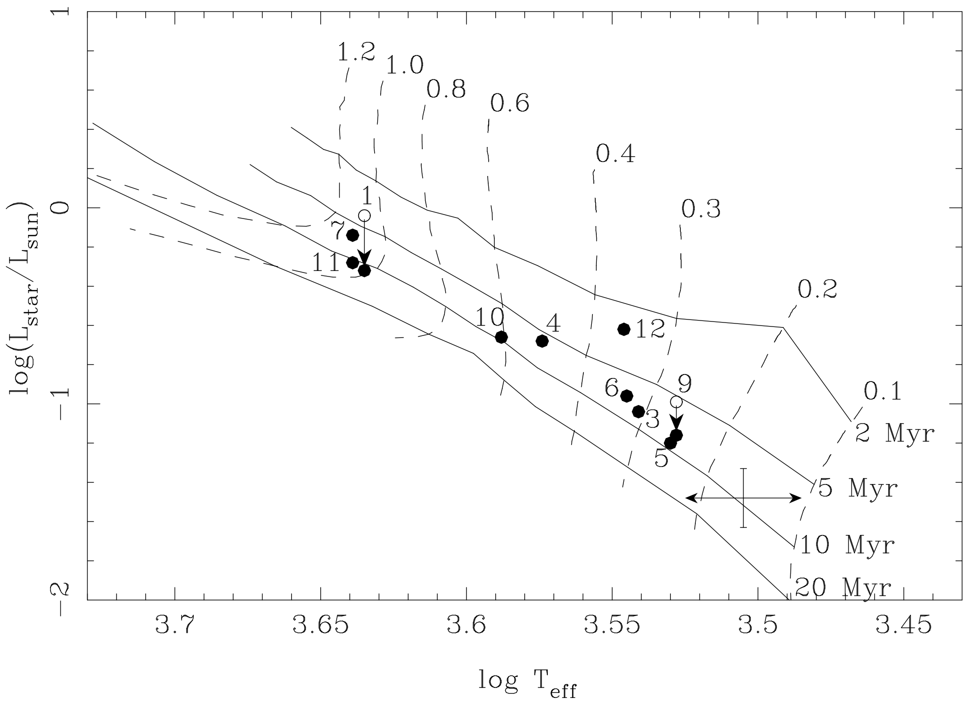

Figure 3. The late-type members of η Cha compared to the models of Siess et al. (2000). For the binaries, the position of the unresolved system and of the components are shown. Both components of RECX1 have about the same luminosity and temperature. RECX9 splits into a primary of the same temperature as the system and a somewhat cooler secondary, indicated by the cross.

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