Photometric study of the OB star clusters NGC 1502 and NGC 2169 and mass estimation of their members at the University Observatory Jena

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Received 2009 Feb 21, accepted 2009 Apr
Published online 2009

Key words: binaries: general – stars: early-type – stars: statistics – open clusters and associations: individual (NGC 1502, NGC 2169)

In this work we present detailed photometric results of the trapezium like galactic nearby OB clusters NGC 1502 and NGC 2169 carried out at the University Observatory Jena. We determined absolute $BVRI$ magnitudes of the mostly resolved components using Landolt standard stars. This multi colour photometry enables us to estimate spectral type and absorption as well as the masses of the components, which were not available for most of the cluster members in the literature so far, using models of stellar evolution. Furthermore, we investigated the optical spectrum of the components ADS 2984A and SZ Cam of the sextuple system in NGC 1502. Our spectra clearly confirm the multiplicity of these components, which is the first investigation of this kind at the University Observatory Jena.

1 Introduction

The CCDM catalogue (Catalogue of the Components of the Double and Multiple stars, Dommel & Nys 2000) lists sixteen, not necessarily physical bound, components of the OB star cluster NGC 1502 (see Fig. 1). The two brightest members with almost equal magnitudes, ADS 2984A and SZ Cam, were first noticed as visual double stars by Struve in 1830. Both stars are spectroscopic binaries themselves (see Plaskett 1924; Morgan, Code & Withford 1955; Budding 1975) with periods of a few days orbiting a third body, which is also a (single lined) spectroscopic binary (Lorenz, Mayer & Drechsel 1998) with a long term period between 50 and 60 years. This rare configuration of a hierarchical sextuple system is interesting regarding to star forming processes (Zinnecker & Yorke 2007). While Hipparcos lists a parallax value with a large error of $0.48 \pm 7.69$ mas, i.e. 2100 pc, Lorenz, Mayer & Drechsel (1998) obtained 1050 pc from speckle interferometric results using the radial velocity curves and 836–870 pc from photometric distance estimation for this sextuple system, whereas Chambliss (1992) gives 600 pc. Guthnick & Prager (1930) first discovered the variable behaviour of SZ Cam, which is investigated by Lorenz, Mayer & Drechsel (1998) in $UBV$.

In contrast to this well investigated cluster only a few parameters of NGC 2169 are available. This cluster also hosts sixteen members (CCDM, see Fig. 2) with visual magnitudes $V \sim 7$ to 10 mag and seems to be quite similar to NGC 1502 and we thus expect a comparable multiplicity. The distance of this cluster given in the Hipparcos catalogue corresponds to $376$ pc ($2.66 \pm 1.60$ mas), while Echevarría, Roth & Warman (1979) list $639$ pc. They investigated $UBVRI$ photometry of the members A+B, C, D and E.

We present $BVRI$ photometry obtained with the Cassegrain-Telescop-Kamera (CTK, see Mugrauer 2009 for a detailed description of this instrument) of all sixteen members listed in the CCDM catalogue of both clusters together with estimations of the absorption in the visible band ($A_V$) caused by the interstellar medium, spectral type and mass as well as spectra of the spectroscopic binaries ADS 2984A and SZ Cam done with the FIASCO (Mugrauer & Avila 2009) spectrograph at the University Observatory Jena.

This work is the first step of further detailed investigations of trapezium like galactic clusters and is part of a search strategy for radio-quiet, nearby neutron stars described in Hohle, Neuhäuser & Tetzlaff (2008). Most of the stars in these clusters are likely massive supernova progenitors in a relatively small volume.

2 Absolute photometry of NGC 1502 and NGC 2169

We took 90 images of NGC 2169 (30 each in $BRI$ with twelve, four and five seconds exposure time for the different filters) in the first night (January 8) and 118 in the second (January 9) with ten seconds exposure for 28 images in the
Fig. 1 The OB star cluster NGC 1502 observed with CTK in the B filter. All 30 B-band images from the first observing night are averaged to the image shown here. The designation of the components follows the CCDM catalogue.

$B$ band and 30 images in $VRI$ with three seconds exposure time each. For NGC 1502 we took 116 images in $BVRI$ (26 in $B$ with twelve seconds exposure time, 30 images in $VRI$ with two seconds exposure each) in the first night and 119 in the second (30 in $B$ with six seconds exposure time, 29 in the $V$ and 30 in the $R$ band with two seconds each and 30 images in $I$ with 1.5 s) for absolute photometry.

All images are flat fielded and dark subtracted. In some images illumination effects due to the bright moon are visible. Therefore we applied a subtractive illumination correction using the source extractor (SE, see Bertin & Arnout 1992), which uses a mesh based background subtraction with a mesh size of 64 pixels. The objects are detected by thresholding with reference to that mesh based background. This background is finally removed from all images. We determined instrumental magnitudes for all sources detected in the individual CTK images in all filters using aperture photometry in ESO-MIDAS (Banse et al. 1987); the aperture radius used in our image for the source photons is 9.8′′, the background was measured in a ring around the source with radii between 32.5″ and 47.7″.

For absolute photometry we observed the Landolt field SA 96 (Landolt 1992; Galadí-Enríquez et al. 2000) four times in the first night and three times in the second night (see Table 1). We accomplished the magnitude calibration with the stars SA 96 405 and SA 96 406 in this field. The aperture radius used in our image for the source photons is 9.8″, the background was measured in a ring around the source with radii between 32.5″ and 47.7″.

Table 1 Observations of the Landolt field SA 96 at the University Observatory Jena for absolute photometry done for four different air masses in the first night and three air masses in the second night with the CTK.

| Images | Filter | Exp. [s] | Images | Filter | Exp. [s] |
|--------|--------|----------|--------|--------|----------|
| 2      | B      | 90       | 2      | B      | 90       |
| 2      | V      | 25       | 2      | V      | 25       |
| 2      | R      | 20       | 2      | R      | 20       |
| 2      | I      | 25       | 2      | I      | 25       |
| 3      | B      | 90       | 2      | B      | 70       |
| 4      | V      | 25       | 2      | V      | 20       |
| 2      | R      | 20       | 2      | R      | 15       |
| 2      | I      | 25       | 2      | I      | 20       |
| 2      | B      | 90       | 3      | B      | 70       |
| 2      | V      | 25       | 2      | V      | 20       |
| 2      | R      | 20       | 2      | R      | 15       |
| 2      | I      | 25       | 2      | I      | 20       |

where $Y$ is the airmass. In order to reduce the effect of extinction due to changing airmass ($k\cdot Y$) we always determined the calibrated magnitudes of all detected objects in the individual CTK images. Except the K component in NGC 2169 (see Fig. 2), all objects have a sufficient amount of counts. The determined values for the different filters are given in Table 2.

For NGC 1502 the central region of the cluster is barely resolved, thus the PSFs of these objects are merged and the
Table 2  Derived zero points \( c \) (normalized for 1s exposure) and atmospheric extinction coefficients \( k \) for \( BVRi \) filters measured during the two observation nights at the University Observatory Jena with the CTK.

| Filter | Zero Point \( c \) | Extinction \( k \) |
|--------|------------------|------------------|
|        | 2009 January 8   |                  |
|        | \( B \) 17.805 ± 0.023 | 0.289 ± 0.012 |
|        | \( V \) 18.776 ± 0.015 | 0.152 ± 0.008 |
|        | \( R \) 18.790 ± 0.016 | 0.104 ± 0.008 |
|        | \( I \) 18.251 ± 0.020 | 0.058 ± 0.010 |
|        | 2009 January 9   |                  |
|        | \( B \) 17.889 ± 0.011 | 0.285 ± 0.006 |
|        | \( V \) 18.874 ± 0.017 | 0.164 ± 0.009 |
|        | \( R \) 18.833 ± 0.020 | 0.110 ± 0.010 |
|        | \( I \) 18.292 ± 0.020 | 0.080 ± 0.011 |

light of neighbouring objects contaminates in the individual apertures. These measurements are excluded from the analysis.

While for NGC 2169 only the A and B components are not resolved (hereafter A+B) and the K component is too faint, for NGC 1502 the C and G (C+G), H and I (H+I) and K and L (K+L) components could not be resolved. The unresolved objects will be treated as one object.

3 Spectra of ADS 2984A and SZ Cam

In addition to the photometric measurements of all components of the cluster NGC 1502 we also obtained spectra of its two brightest components, namely ADS 2984A (A component) and SZ Cam (B component). Since both stars are very close to each other and have very similar photometric and spectroscopic properties, they are often mixed up (see Lorenz, Mayer & Drechsel 1998, address some catalogues with wrong designations, to avoid further confusion).

The spectra were taken with the fiber spectrograph FIASCO, which is installed at the Nasmyth focus of the University Observatory Jena. The spectrograph exhibits a dispersion of \( \sim 0.91 \text{ Å/pixel} \) and a resolving power of \( R \sim 5500 \) at the wavelength of H\( \alpha \). In its actual configuration FIASCO is adjusted to cover the wavelength range from about 6130 up to 7060 Å. For a detailed overview of all properties of the spectrograph we refer here to Mugrauer & Avila (2009).

Spectra of ADS 2984A and SZ Cam were taken with FIASCO one after another at similar airmass in two nights on 2008 October 18 and November 16. Three 2 min spectra of each star were taken in October 2008, and two 600 s spectra for each in November, respectively. For calibration we always took three dark frames with the same integration time as chosen for spectroscopy. Flat field and arc-lamp images were taken with the integrated calibration unit of the spectrograph. The reduction of all data, the extraction of the spectra from the individual images, as well as their wavelength calibration was done with standard IRAF tasks for the reduction of spectroscopic data. The individual reduced and calibrated spectra of each star were finally averaged, and the continuum was then normalized to one.

Figures 3 and 4 show the normalized spectra of both components from October 2008. In addition, we also show normalized spectra of dwarfs, taken from the spectral library of Le Borgne et al. (2003) for comparison.

The FIASCO spectra of both components are very similar to each other. Beside the telluric absorption features of oxygen at 6277 Å and 6867 Å, the absorption lines of H\( \alpha \) at 6563 Å, as well as of He I at 6678 Å are clearly detected. In the FIASCO spectra the H\( \alpha \) and He I line are both fainter than in the B0V comparison spectrum, which indicates a spectral type of both components earlier than B0. The detected H\( \alpha \) lines fit well with that of the O5V comparison spectrum, while the He I lines are both stronger, consistent with O-type stars with a spectral type later than O5. Hence, from our FIASCO spectroscopy we can conclude that the spectral type of ADS 2984A and SZ Cam should range between O5 and B0.

Details of all FIASCO spectra, centered around the H\( \alpha \)-line, are shown in Fig. 5 for ADS 2984A, and in Fig. 6 for
The variability of the Hα line from the A component of NGC 1502 (ADS 2984A) caused by a massive companion, see Lorenz, Mayer & Drechsel (1998). Both spectra are fixed on the telluric oxygen absorption features (see Figs. 3 and 4) and are constant to the diffuse interstellar band (DIB). Spectra were taken with about one month of epoch difference.

Fig. 6  Same as in Fig. 5 but for SZ Cam. This system is known as double lined spectroscopic binary consisting of a O9 IV and B0 V star, see Lorenz, Mayer & Drechsel (1998).

SZ Cam, respectively. Beside the strong hydrogen line our FIASCO spectra also show the absorption line of diffuse interstellar bands (DIB) at 6614 Å. We determined the center of the DIB and Hα line in all spectra using Gaussian line fitting with ESO-MIDAS. Between October and November 2008 we do not find a significant shift of the DIB line in the two spectra of each stars. In contrast, in the spectra of both stars a significant shift of the Hα line-center is detected between both observing epochs. We find a shift of the Hα line-center of $-1.99 \pm 0.14$ Å in the case of ADS 2984A and $-0.87 \pm 0.13$ Å for SZ Cam, respectively. The shift of the Hα line between both observing epochs induced by the change of the heliocentric velocity is expected to be only $-0.21$ Å. Hence, the detected line shifts in the spectra of ADS 2984A and SZ Cam clearly confirm that they are both spectroscopic multiple systems. This spectroscopic investigation of well known binaries shows that the conditions at the University Observatory Jena are sufficient to detect binaries in comparable OB clusters in further investigations. ADS2984A, as well as SZ Cam are both known as double lined spectroscopic binaries (Lorenz, Mayer & Drechsel 1998). The detection of the double lined spectroscopic nature of massive binaries like ADS2984A, or SZ Cam is challenging with FIASCO, discernible only as a small asymmetry of their line profiles (see e.g. Fig. 6). However, with multi-epoch radial velocity measurements the multiplicity of these stars can be clearly revealed with FIASCO.

4 Results

4.1 Magnitudes, colours, absorptions, and spectral types

Starting from absolute $BVJHK$ magnitudes and colours we have enough information to calculate the $A_V$ values for given spectral types (as listed in Simbad) of the members. The (constant) ratios of $A_V$ to the absorptions of different bands $X$, i.e. $A_V/A_X$, are given in the models of Rieke
Table 3  Medians of the magnitudes of the components of NGC 1502. The errors are the mean error of the single images. The $A_V$ values of each member are calculated from the median of the $A_V$ values obtained from the different $BVJHK$ colours, the error denotes the standard deviation. The $BVRI$ magnitudes listed here are obtained with the CTK, while $JHK$ are 2MASS magnitudes.

| Component | $B$ [mag] | $V$ [mag] | $R$ [mag] | $I$ [mag] | $A_V(BVJHK)$ [mag] |
|-----------|-----------|-----------|-----------|-----------|---------------------|
| A         | 7.349 ± 0.027 | 6.880 ± 0.018 | 6.563 ± 0.018 | 6.271 ± 0.022 | 1.93 ± 0.08 |
| B         | 7.338 ± 0.027 | 6.910 ± 0.018 | 6.635 ± 0.018 | 6.387 ± 0.022 | 2.13 ± 0.04 |
| C+G       | 7.351 ± 0.027 | 6.880 ± 0.018 | 6.838 ± 0.018 | 6.954 ± 0.022 | - |
| D         | 9.890 ± 0.027 | 9.401 ± 0.019 | 9.112 ± 0.018 | 8.820 ± 0.022 | 1.94 ± 0.00 |
| E         | 11.571 ± 0.033 | 11.003 ± 0.026 | 10.572 ± 0.022 | 10.163 ± 0.026 | - |
| F         | 7.352 ± 0.027 | 6.880 ± 0.018 | - | - | - |
| G+C       | 7.351 ± 0.027 | 6.880 ± 0.018 | 6.838 ± 0.018 | 6.954 ± 0.022 | - |
| H+I       | 9.734 ± 0.027 | 9.187 ± 0.019 | 8.854 ± 0.018 | 8.524 ± 0.022 | - |
| J         | 10.273 ± 0.027 | 9.732 ± 0.019 | 9.406 ± 0.018 | 9.083 ± 0.022 | 1.69 ± 0.15 |
| K+L       | 10.316 ± 0.027 | 9.771 ± 0.019 | 9.437 ± 0.018 | 9.090 ± 0.022 | - |
| M         | 11.616 ± 0.033 | 11.008 ± 0.026 | 10.515 ± 0.027 | 10.589 ± 0.031 | - |
| N         | 10.159 ± 0.027 | 9.589 ± 0.019 | 9.242 ± 0.018 | 8.894 ± 0.022 | 2.23 ± 0.11 |
| O         | 11.487 ± 0.031 | 10.843 ± 0.023 | 10.462 ± 0.020 | 10.031 ± 0.024 | 2.64 ± 0.09 |
| P         | 12.091 ± 0.039 | 11.500 ± 0.033 | 11.132 ± 0.027 | 10.722 ± 0.031 | - |

Table 4  Same as in Table 3 but with the cluster NGC 2169. The P component is not listed in 2MASS, i.e. we derived the $A_V$ value from $B - V$ measured from this work only.

| Component | $B$ [mag] | $V$ [mag] | $R$ [mag] | $I$ [mag] | $A_V(BVJHK)$ [mag] |
|-----------|-----------|-----------|-----------|-----------|---------------------|
| A+B       | 6.853 ± 0.022 | 6.906 ± 0.022 | 6.962 ± 0.031 | 6.976 ± 0.028 | 0.49 ± 0.04 |
| C         | 11.198 ± 0.035 | 10.948 ± 0.029 | 11.093 ± 0.042 | 10.703 ± 0.037 | 0.14 ± 0.42 |
| D         | 8.562 ± 0.022 | 8.599 ± 0.022 | 8.649 ± 0.031 | 8.638 ± 0.028 | 0.69 ± 0.05 |
| E         | 9.173 ± 0.022 | 9.134 ± 0.022 | 9.133 ± 0.031 | 9.069 ± 0.028 | 0.81 ± 0.08 |
| F         | 11.028 ± 0.030 | 9.891 ± 0.022 | 9.336 ± 0.031 | 8.761 ± 0.028 | 1.04 ± 0.07 |
| G         | 11.923 ± 0.052 | 11.836 ± 0.046 | 11.830 ± 0.065 | 11.710 ± 0.071 | - |
| H         | 11.034 ± 0.034 | 10.896 ± 0.027 | 10.861 ± 0.038 | 10.703 ± 0.037 | - |
| I         | 8.713 ± 0.022 | 8.745 ± 0.022 | 8.795 ± 0.031 | 8.779 ± 0.028 | 0.52 ± 0.04 |
| J         | 10.807 ± 0.028 | 10.757 ± 0.026 | 10.760 ± 0.037 | 10.682 ± 0.036 | 0.69 ± 0.09 |
| L         | 10.851 ± 0.028 | 10.761 ± 0.026 | 10.793 ± 0.037 | 10.598 ± 0.035 | 0.44 ± 0.02 |
| M         | 11.148 ± 0.032 | 11.025 ± 0.029 | 10.959 ± 0.040 | 10.853 ± 0.039 | 0.71 ± 0.07 |
| N         | 8.058 ± 0.022 | 8.061 ± 0.022 | 8.073 ± 0.031 | 8.071 ± 0.028 | 0.54 ± 0.04 |
| O         | 11.243 ± 0.030 | 11.111 ± 0.029 | 11.083 ± 0.041 | 10.915 ± 0.039 | 0.83 ± 0.13 |
| P         | 10.579 ± 0.028 | 10.531 ± 0.025 | 10.542 ± 0.035 | 10.449 ± 0.034 | 0.35 ± 0.16 |

& Lebofsky (1979), Savage & Bolton (1979), and Cardelli, Clayton & Mathis (1989), whereas we used the medians of the different values from the different authors of each ratio. The stellar atmosphere models of Bessell, Castelli & Plez (1998) provide for each effective temperature the model colours $B - V$, $V - R$ and $V - I$, and bolometric corrections up to 50000 K, and Kenyon & Hartmann (1995) list $B - V$, $V - J$, $V - H$ and $V - K$, and bolometric corrections for B0 and later. Moreover, Schmidt-Kaler (1982) lists bolometric corrections for stars earlier than B0, which completes our model data.

With given model colours and the measured data we estimated the absorption by calculating the $A_V$ values in each band. The formal errors of the $A_V$ values are derived by the errors of the measured magnitudes and colours. The $A_V$ values from $B - V$, $V - J$, $V - H$, and $V - K$ for both clusters are shown in Figs. 7 and 8 and almost all of them follow a one-to-one relation within their one sigma error bars, although there is a tendency for a systematic deviation from this relation for both clusters. This is maybe caused due to the different ratios of $A_V$ to the absorptions of different bands in different directions, which contradicts the constant ratios assumed by the models, mentioned before. We calculated the medians of the $A_V$ values and their standard deviation and list them in Tables 5 and 4.

While the median value of absorption of the unresolved binary SZ Cam is $A_V = 2.13 ± 0.04$ mag from our calculations (and 2.16 ± 0.18 mag from $B - V$ only), Crawford (1994) lists 2.32 mag from $B - V$. Lorenz, Mayer & Drechsel (1998) give a total visual magnitude of $V = 6.92$ mag for SZ Cam (6.910 ± 0.018 from own photometry) and
Table 5  Spectral types as listed in Simbad (for second line from Lorenz, Mayer & Drechsel 1998) and masses for NGC 1502. The mass determination is based on the luminosity and, hence the assumed distance (here 836 pc and 1050 pc, see Lorenz, Mayer & Drechsel 1998). The errors for the luminosities are derived from the two distances, while the mean value is given. The mass values are obtained using the evolutionary models from Bertelli et al. (1994) (B), Claret (2004) (C) and Schaller et al. (1992) (S).

| Component | Sp. Type | log $L_{bol}$ | Mass for 836 pc | Mass for 1050 pc |
|-----------|----------|---------------|----------------|-----------------|
|           |          | [L$_\odot$]   | B   | C   | S   | Mean ± Std. | B   | C   | S   | Mean ± Std. |
| A         | B0II     | 4.71$^{+0.09}_{-0.11}$ | 13.0 | 15.6 | 14.8 | 14.5 ± 1.3 | 14.9 | 15.5 | 14.7 | 15.1 ± 0.4 |
| B         | O9 IV    | 4.86$^{+0.09}_{-0.11}$ | 19.0 | 19.8 | 19.8 | 19.5 ± 0.5 | 22.1 | 19.8$^1$ | 22.2 | 21.4 ± 1.4 |
|           | + B0V    | 4.49$^{+0.09}_{-0.11}$ | 14.7 | 15.8 | 15.0 | 15.2 ± 0.6 | 17.1 | 17.7 | 14.8 | 16.6 ± 1.5 |
| D         | B2V      | 3.71$^{+0.09}_{-0.11}$ | 8.5  | 7.9  | 9.0  | 8.5 ± 0.5  | 9.0  | 10.0 | 9.0  | 9.3 ± 0.5  |
| J         | B8V      | 2.89$^{+0.09}_{-0.11}$ | 4.2  | 4.0  | 4.8  | 4.3 ± 0.4  | 4.6  | 5.0  | 4.3  | 4.6 ± 0.4  |
| N         | B1V      | 3.87$^{+0.09}_{-0.11}$ | 9.8  | 10.0 | 9.0  | 9.6 ± 0.5  | 11.0 | 10.0 | 9.0  | 10.0 ± 1.0 |
| O         | B1.5V    | 3.53$^{+0.09}_{-0.11}$ | 7.9  | 7.9  | 7.0  | 7.6 ± 0.5  | 8.8  | 7.9  | 9.0  | 8.6 ± 0.6  |

$^1$ for Z=0.04, because the model for solar metallicity produces 6.6 M$_\odot$, which is obviously inconsistent with the other masses.

Table 6  Same as in Table 5, but with the cluster NGC 2169. Masses are calculated for the distance listed in Hipparcos (376 pc) and Roth & Warman (1979) (639 pc). The masses for the smaller distance seem to be too small for the corresponding spectral types, i.e. the 639 pc is more realistic. Although in this case the masses of the components C, D, M, O and P are too small (P has no 2MASS magnitudes). These stars probably do not belong to this cluster and may have a larger distance.

| Component | Sp. Type | log $L_{bol}$ | Mass for 376 pc | Mass for 639 pc |
|-----------|----------|---------------|----------------|----------------|
|           |          | [L$_\odot$]   | B   | C   | S   | Mean ± Std. | B   | C   | S   | Mean ± Std. |
| A         |           |               |     |     |     |             |     |     |     |             |
| B         |           |               |     |     |     |             |     |     |     |             |
| C         | B2V      | 3.61$^{+0.17}_{-0.29}$ | 7.4  | 7.9  | 7.0  | 7.5 ± 0.5  | 9.1  | 10.0 | 9.0  | 9.4 ± 0.6  |
| D         | B1V      | 1.61$^{+0.17}_{-0.29}$ | 1.6  | 1.6  | 1.6  | 1.6 ± 0  | 2.1  | 2.0  | 1.8  | 2.0 ± 0.1  |
| E         | B3V      | 2.70$^{+0.17}_{-0.29}$ | 5.3  | 5.0  | 4.6  | 5.0 ± 0.3 | 7.1  | 6.3  | 7.0  | 6.8 ± 0.4  |
| F         | G8V      | 2.13$^{+0.17}_{-0.29}$ | 4.1  | 4.0  | 3.7  | 3.9 ± 0.2 | 5.6  | 5.0  | 4.7  | 5.1 ± 0.4  |
| I         | B3V      | 2.75$^{+0.17}_{-0.29}$ | 2.4  | 2.3  | 1.6  | 2.1 ± 0.4 | 3.0  | 3.2  | 2.5  | 2.9 ± 0.3  |
| J         | B5       | 1.79$^{+0.17}_{-0.29}$ | 4.2  | 4.0  | 3.8  | 4.0 ± 0.2 | 5.6  | 5.0  | 4.7  | 5.1 ± 0.5  |
| L         | A0       | 1.28$^{+0.17}_{-0.29}$ | 2.3  | 2.2  | 2.2  | 2.2 ± 0.1 | 3.1  | 3.2  | 2.8  | 3.0 ± 0.2  |
| M         | B9.5     | 1.36$^{+0.17}_{-0.29}$ | 1.7  | 1.8  | 1.6  | 1.7 ± 0.1 | 2.3  | 2.0  | 1.8  | 2.0 ± 0.2  |
| N         | B2.5V    | 1.01$^{+0.17}_{-0.29}$ | 1.8  | 1.8  | 1.6  | 1.7 ± 0.1 | 2.4  | 2.5  | 2.5  | 2.5 ± 0.1  |
| O         | B9V      | 1.37$^{+0.17}_{-0.29}$ | 5.0  | 5.0  | 4.8  | 4.9 ± 0.1 | 6.4  | 6.3  | 6.2  | 6.3 ± 0.1  |
| P         | B9V      | 0.96$^{+0.23}_{-0.43}$ | 1.8  | 1.8  | 1.8  | 1.8 ± 0  | 2.4  | 2.5  | 2.5  | 2.5 ± 0.1  |

$V = 7.7$ and 8.63 mag for the resolved components. We use these values for the mass estimation in the next section.

4.2 Mass estimation

Knowing $V$-band magnitudes, bolometric corrections, and absorptions one can calculate the luminosity for a given distance and from spectral type we derived the temperature. With temperature and luminosity we can now estimate the mass of the star using model grids of stellar evolution by putting the star into the HR-Diagram. Assuming solar metallicity we used the models from Bertelli et al. (1994) (up to 35 M$_\odot$), Schaller et al. (1992) and Claret (2004) (both up to 125 M$_\odot$). We interpolated linearly between the evolutionary tracks. Each model takes mass loss into account.

Since the luminosity is very sensitive to the parallax, we calculated the mass for 836 pc and 1050 pc, see Lorenz, Mayer & Drechsel (1998) for NGC 1502 and for 376 pc (Hipparcos) and 639 pc (Roth & Warman 1979) for NGC 2169. For some components the mass value is obviously not consistent to the spectral type (see Tables 5 and 6). Likely these stars do not belong to the cluster and are more distant (C, D, M, O and P in NGC 2169). Unfortunately almost none of these stars have trigonometric parallaxes in Hipparcos, so that we cannot prove this claim directly. Only the A and B components for both clusters and I and N for NGC 2169 have Hipparcos parallaxes (the parallax value for
the D component in NGC 2169 has a negative value), but the latter ones have reasonable masses within their errors and the parallaxes correspond to 600–660 pc for both. As discussed in the first section, the distances of both clusters are rarely known and have a strong influence on the resulting masses obtained from the luminosities. The WEBDA data base gives 1052 pc for NGC 2169, which differs much from these distances used in Tables 6 and would increase the masses significantly. This has to be considered if ages and residual life times (derived from the masses) are used for further investigations as suggested in Hohle, Neuhaüser & Tetzlaff (2008).

From radial velocity curves of SZ Cam it is known that both components have 15 and 11 M⊙ (Lorenz, Mayer & Drechsel 1998), i.e. 26 M⊙ together. The mass estimation from the luminosity of this component, which is unresolved in the CTK, results in 19.5 ± 0.5 and 15.2 ± 0.6 M⊙ or 21.4 ± 1.4 and 16.6 ± 1.5 M⊙ for a distance of 836 pc or 1050 pc, respectively (see Table 5, component B), using the visual magnitudes given in Lorenz, Mayer & Drechsel (1998).

5 Conclusion

We performed absolute BVRI photometry at the University Observatory Jena with the Cassegrain-Telescop-Kamera (CTK) of sixteen members (as listed in the CCDM) of the OB clusters NGC 1502 and NGC 2169 including those stars which were not measured in Hipparcos. We calculated the absorption due to the interstellar medium for the components with known spectral type using colour models. Moreover, we estimated the masses of these stars, using BVJHK photometry for different distances of each cluster. The obtained values for masses and absorptions are reliable for the inner components of the cluster, but for the outer components the mass tends to too low values. These stars likely do not belong to the clusters physically and have a larger distance. The mass estimation based on the luminosities of the stars strongly depends on the assumed distance.

Since NGC 1502 is relatively well investigated and our methods work in general, NGC 2169 should be an object for further investigations for spectroscopy. As described in Sect. 3, we are able to detect the multiple character of individual cluster components with FIASCO at the 90 cm telescope of the University Observatory Jena, which was done for the first time at this Observatory. Thus, a detailed spectroscopic monitoring of NGC 2169 seems promising for further binary detections.

Acknowledgements. RN acknowledges general support from the German National Science Foundation (Deutsche Forschungsgemeinschaft, DFG) in grants NE 515/13-1, 13-2, and 23-1, SR and MV acknowledge support from the EU in the FP6 MC ToK project MTKD-CT-2006-042514, TOBS acknowledges support from the Evangelisches Studienwerk e.V. Villigst, TE, NT and MMH acknowledge partial support from DFG in the SFB/TR-7 Gravitation Wave Astronomy and MM acknowledges support from the government of Syria. Furthermore we acknowledge the 2MASS point source catalogue.

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