HIP 3678: a hierarchical triple stellar system in the centre of the planetary nebula NGC 246

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ABSTRACT
We report the detection of a new low-mass stellar companion to the white dwarf HIP 3678 A, the central star of the planetary nebula NGC 246. The newly found companion is located about 1 arcsec (at projected separation of about 500 au) north-east of HIP 3678 A, and shares a common proper motion with the white dwarf and its known comoving companion HIP 3678 B. The hypothesis that the newly detected companion is a non-moving background object can be rejected on a significance level of more than 8σ, by combining astrometric measurements from the literature with follow-up astrometry, obtained with Wide Field Planetary Camera 2/Hubble Space Telescope and NACO/Very Large Telescope. From our deep NACO imaging data, we can rule out additional stellar companions of the white dwarf with projected separations between 130 up to 5500 au. In the deepest high-contrast NACO observation, we achieve a detection limit in the Ks band of about 20 mag, which allows the detection of brown dwarf companions with masses down to 36MJup at an assumed age of the system of 260 Myr. To approximate the masses of the companions HIP 3678 B and C, we use the evolutionary Baraffe et al. models and obtain about 0.85M⊙ for HIP 3678 B and about 0.1M⊙ for HIP 3678 C. According to the derived absolute photometry, HIP 3678 B should be a early to mid-K dwarf (K2–K5), while HIP 3678 C should be a mid M dwarf with a spectral type in the range between M5 and M6.

Key words: astrometry – binaries: visual – white dwarfs – planetary nebulae: individual: NGC 246.

1 INTRODUCTION
NGC 246, also known as the ‘Skull Nebula’ is a planetary nebula in the constellation Cetus, which was first observed by W. Herschel in 1785. The nebula exhibits a slightly elliptical morphology with a diameter of about 224 arcsec in average (Cahn, Kaler & Stanghellini 1992), a temperature of about 20 000 K, and shows Ne v and O vi emission lines in its far-ultraviolet spectrum, as measured with the Far-Ultraviolet Spectroscopic Explorer (FUSE), indicating photoionization from the intense UV-radiation of its central star (Hoogerwerf et al. 2007). The nebula was not detected in X-ray, its central star has ROSAT and Chandra detections and shows a non-local thermodynamical equilibrium model consistent PG 1159-type spectrum (Green, Schmidt & Liebert 1986).

HIP 3678 A has a known common proper motion companion, which is located about 3.8 arcsec north-east of its primary star, first noted by Minkowski (1965) and later then confirmed by Cudworth (1973). By fitting photometric measurements of the comoving companion to the zero-age main sequence, Bond & Ciardullo (1999) derived a distance of 495±145 pc for the HIP 3678 system, while Terzian (1997) derived a distance of 570±155 pc, using the parallax expansion method, based on imaging data of the central star of the planetary nebula is HIP 3678 A (alias WD 0044-121), whose proper and parallactic motion was measured by the astrometry satellite Hipparcos (μαcos(δ) = −23.85 ±3.42 mas yr−1 and μδ = −4.89 ± 1.82 mas yr−1, π = 2.12 ± 3.01 mas, as newly determined by van Leeuwen 2007). HIP 3678 A is a very hot O vi sequence (Smith & Aller 1969), or PG 1159-35(lg E) (Werner & Herwig 2006) star with an effective temperature of about 150 000 K, a mass of 0.84 M⊙, and a surface gravity of log(g) ∼ 5.7 (cgs) (Koesterke, Dreizler & Rauch 1998). Whereas the nebula was not detected in X-ray, its central star has ROSAT and Chandra detections and shows a non-local thermodynamical equilibrium model consistent PG 1159-type spectrum (Green, Schmidt & Liebert 1986).

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planet nebula, obtained by Liller, Weltcher & Liller (1966). Additional distances of the planetary nebula were obtained (480 ± 96 pc, and 472 ± 670 pc, by Stanghellini & Haywood 2010, and McDonald, Zijlstra & Boyer 2012, respectively), which well agree with the previous distance estimates. In our research, we adopt here a distance of 504 ± 178 pc, which is the mean and the 1σ-error of the distance values given in the literature, as listed above.

The planetary nebula NGC 246 with its central stellar system is shown in the right-hand panel of Fig. 1. This pattern is a colour-composite image, composed of images from the Digitized all Sky Survey (DSS), which were taken through different optical filters at observing epochs between 1954 and 1994. Assuming a distance of 504 pc, NGC 246 exhibits an averaged projected diameter of about 110 000 au. The elliptical shape of the planetary nebula is clearly visible in the DSS image with its semimajor axis aligned in the east to west direction, consistent with the motion of its central stellar system. The (leading) western shell of NGC 246 appears clearly visible in the DSS image with its semimajor axis aligned in the east to west direction, induced by the motion of the system through space. The western leading edge of the nebular shell is brighter due to its interaction with the interstellar medium. In the WFPC2 and NACO images, the individual components of the HIP 3678 system in the centre of NGC 246 are marked with letters.

In this paper, we present astro- and photometric measurements of the stellar system HIP 3678 in the centre of NGC 246, which were obtained and analysed in the course of our high-contrast imaging survey, to study the multiplicity of B stars in the near-infrared, using imaging data taken with the adaptive optics imager NACO (Lenzen et al. 2003; Rousset et al. 2003) at the Very Large Telescope (VLT), operated by the European Southern Observatory (ESO) in Chile.

The order of this paper is as follows. In Section 2, we describe all details of the individual observations and the applied data-reduction procedures, and present the astrometric calibration of the used instruments. In Section 3, we show all astrometric measurements, as well as the proper motion analysis of the detected companions in the HIP 3678 system. In Section 4, we present the results of our photometric analysis, as well as the mass and age estimation of the detected companions. Finally, in the last section we summarize and discuss all results reported in this work.

2 OBSERVATIONS AND DATA REDUCTION

The near-infrared data of HIP 3678, which are presented here, were taken with NACO in two observing epochs in 2004 and 2007. In 2004, HIP3678 was imaged with NACO's S13 optics in the J, H and Ks band, while in 2007 observations were taken only in the Ks band using NACO's S27 optics. In both observing epochs, the jitter technique was applied to effectively cancel out the bright background of the sky in the near-infrared. Several short integrations (DIT) were taken per jitter position and several of these integrations (NDIT) were then averaged to one image. The target was then observed at several (NINT) different randomly chosen jitter positions located within a jitter-width of 6 arcsec with the S13, and 5 arcsec with the S27 optics.

In addition to the high-contrast near-infrared NACO observations, HIP 3678 was also observed with the Hubble Space Telescope (HST) in 1994 in one observing epoch using the Wide Field Planetary Camera 2 (WFPC2). The fully reduced and calibrated image with a total detector integration time of 2000 s, taken in the F656N filter, was extracted from the HST data-archive. Fig. 1 shows the NACO and HST images of HIP 3678 in the centre of NGC 246.

For the data reduction of the NACO images, we use appropriate calibration data from the ESO data-archive, i.e. darks with the same exposure time, and flats taken in the same filter and in the same night as the science data. In order to reduce all imaging data, we use ESOxS, which is part of ESO’s Common Pipeline Library (ESO CPL). For each science frame a master-dark subtraction and flat-field correction is applied, and all images are averaged with ESOxS, using the provided shift+add procedure including measurement and subtraction of the bright background of the sky in the near-infrared.

All NACO images were astrometrically calibrated [determination of the pixel-scale (PS) and the position angle (DPA) of the NACO detector] using our astrometrical self-calibration technique, as described in detail by Adam et al. (2013). Thereby, the individual NACO science frames are used and shifts induced by the jitter

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1 http://www.eso.org/sci/software/cpl, [ESO CPL Development Team (2014)].
technique are measured in the images, using all detected sources in the images. By comparing these shifts with the offsets of the telescope pointing, as given in the FITS-headers of the individual science frames, the pixel-scale and position angle of the detector can be determined even in the case that no astrometric standards are available for an observing epoch (which is the case here).

In contrast to the NACO observations, HIP 3678 was observed with the HST only at one telescope pointing, hence no astrometrical calibration of the WFPC2 detector for the given observing epoch is available. Therefore, we use here the pixel-scale and detector alignment, as given in world coordinate system (WCS) in the FITS-header of the HST image, extracted from the HST data-archive. Since no uncertainties for the astrometrical calibration are given, the resulting astrometric precision has to be considered as a lower limit.

The used instruments, filters, integration-times, number of taken images, as well as the derived astrometric calibration for all observing epochs, whose data are presented in this work, is summarized in the observation log in Table 1.

### 3 ASTROMETRY

Beside the known bright comoving companion HIP 3678 B, a further faint companion-candidate is detected in the available WFPC2 and NACO images of the central star of NGC 246. The newly detected companion-candidate is located about 1 arcsec north-east of HIP 3678 A. We measure the astrometric position of HIP 3678 A & B, as well as that of the companion-candidate in all imaging epochs, using the astromatic routine. With the astrometric calibration of each observing epoch, the angular separation and position angle of HIP 3678 B and of the companion-candidate relative to HIP 3678 A are derived, which are summarized in Table 1.

With the known proper and parallactic motion of HIP 3678 A, as well as the given epoch differences, we determine the expected angular separations and position angles of HIP 3678 B and of the newly detected faint companion-candidate for all observing epochs, assuming that these sources would be non-moving background objects, using the last observing epoch as reference.

By comparing the measured astrometry of HIP 3678 B and of the detected companion-candidate with the expected astrometry for non-moving background sources, we can check for common proper motion of both objects. The results of this common proper motion analysis are summarized in Table 2 and are illustrated in Fig. 2.

Beside the HST observation taken in 1994 and the NACO imaging data from 2004 and 2007, two further astrometric measurements of HIP 3678 B are given in the literature (Cudworth 1973; Bond & Ciardullo 1999). In addition, the companion is also detected together with its primary star in the 2 Micron All Sky Survey (2MASS), and the astrometric positions of both objects are listed in the 2MASS Point Source Catalog (2MASS-PSC), see Skrutskie et al. (2006).

HIP 3678 B is located about 3.9 arcsec south-east of HIP 3678 A at a position angle of about 130°. Within the given total epoch difference between the first and the latest observing epoch of about 35 yr, the astrometry of HIP 3678 B significantly deviates from the expected one for a non-moving background object. We can reject this background hypothesis for the companion at a significance level of more than 8σ, in total (2.8σ in angular separation and 5.9σ in position angle, respectively). Hence, our astrometric analysis significantly confirms that HIP 3678 B is a common proper motion companion of the white dwarf HIP 3678 A. Assuming a physical relation of both stars, at a distance of 504 pc the measured angular

### Table 1. Observation log and astrometric calibration of all instruments and for all observing epochs, whose data are presented in this work. All NACO images are astrometrically calibrated using our self-calibration technique, while the pixel-scale (PS) and the detector position angle (DPA) of the HST observation are taken from WCS of the HST FITS-file.

| Date         | Camera       | Filter | Exposure time | PS       | DPA  |
|--------------|--------------|--------|---------------|----------|------|
| 1994-07-27   | WFPC2/HST    | F656N  | 1000 × 1 × 2  | 0.153    | 0.0  |
| 2004-11-22   | NACO-S13/VLT | J      | 9 × 8 × 5     | 13.189   | -0.012 |
|              | NACO-S13/VLT | H      | 3.6 × 20 × 5  | 13.259   | -0.027 |
|              | NACO-S13/VLT | Ks     | 0.6 × 20 × 5  | 13.182   | -0.082 |
| 2007-06-14   | NACO-S27/VLT | Ks     | 40 × 5 × 15   | 27.285   | 0.153  |

### Table 2. Astrometry of the HIP 3678 system. We show the measured angular separation and position angle of HIP 3678 B & C relative to their primary star HIP 3678 A for all observing epochs. In the columns Sig.-level (background), we list the significance level to reject the background hypothesis for both companions relative to the latest observing epoch.

| Object | Observing epoch (YYYY-MM-DD) | Reference | Angular separation (arcsec) | Sig.-level (background) (σ) | Position angle (°) | Sig.-level (background) (σ) |
|--------|-------------------------------|-----------|---------------------------|---------------------------|-------------------|---------------------------|
| HIP 3678 B | 1972-07-02 | Cudworth (1973) | 3.80 ± 0.10 | 2.8 | 129.0 ± 1.0 | 5.9 |
|       | 1989-09-24 | Bond & Ciardullo (1999) | 3.81 ± 0.01 | 3.2 | 130.3 ± 0.2 | 5.5 |
|       | 1994-03-17 |                        | 3.84 ± 0.02 | 3.2 | 130.5 ± 0.2 | 4.7 |
|       | 1998-10-02 | 2MASS-PSC           | 3.83 ± 0.12 | 0.6 | 130.1 ± 1.6 | 1.5 |
|       | 2004-11-22 |                        | 3.85 ± 0.04 | 0.4 | 129.9 ± 0.5 | 1.3 |
|       | 2007-06-14 |                        | 3.90 ± 0.03 | –   | 130.1 ± 0.4 | –   |
| HIP 3678 C | 1994-03-17 |                        | 1.02 ± 0.02 | 6.1 | 51.8 ± 1.9 | 2.7 |
|       | 2004-11-22 |                        | 1.03 ± 0.10 | 3.2 | 52.8 ± 0.5 | 1.7 |
|       | 2007-06-14 |                        | 1.05 ± 0.01 | –   | 52.9 ± 0.6 | –   |
Figure 2. The proper motion diagrams for angular separation (left) and position angle (right) over time for HIP 3678 B (top), and the newly detected co-companion HIP 3678 C (bottom), respectively. The area of maximal possible orbital motion for a circular edge-on (for separation), or a pole-on (for position angle) orbit of a physically bound system are indicated by dotted (black) lines. The dashed (red) lines mark the (greyish) area where we would expect a non-moving background object, derived with the known proper and parallactic motion of HIP 3678 A.

separation of the comoving companion corresponds to a projected separation of about 1900 au, which yields a minimal orbital period of about 60 000 yr, assuming a total mass of the HIP 3678 system of about 1.8 M⊙ (see below).

In contrast to HIP 3678 B, the newly found faint companion-candidate is imaged only in three observing epochs with a total epoch difference of about 13 yr. According to the common proper motion analysis, we can reject the background hypothesis for this candidate at a significance level of more than 8σ in total (6.1σ in angular separation and 2.7σ in position angle, respectively). Hence, this object is a further comoving companion of HIP 3678 A, which therefore will be designated as HIP 3678 C, from hereon. At the distance of the HIP 3678 system, the angular separation of HIP 3678 C relative to its primary star is about 500 au (minimal orbital period of about 11000 yr for an assumed total mass of the HIP 3678 AC system of about 1 M⊙, see below), which makes the central star of the planetary nebula NGC 246 a hierarchical triple, composed of a close binary (including the white dwarf), which exhibits a further companion at a wider separation.

For both HIP 3678 B and C, we did not find any significant drifts in angular separation and/or position angle, which could be an indication for detected orbital motion, as it is also expected by taking into account the given astrometric uncertainties and long orbital periods of the companions.

4 PHOTOMETRY

Photometric measurements of HIP 3678 A and of its two comoving companions were obtained with NACO during the imaging epoch in 2004. Observations were carried out in the J, H and Ks band and the photometric standard star GSPC S677-D, whose photometry

\[ \alpha(J2000) = 23^{h}32^{m}34^{s}.5, \delta(J2000) = -15^{\circ}21^{\prime}06^{\prime\prime} \]
is listed in the 2MASS-PSC,\(^3\) was observed in the same night at air mass differences to the HIP 3678 system, which were always smaller than 0.03 dex.

The instrumental magnitudes of the individual components of the HIP 3678 system, as well as those of the standard star are measured in all bands with aperture photometry using the IDL/aper routine. In the case of the close binary HIP 3678 AC, the contamination of the photometry due to the components on each other is taken into account by subtracting the individual point spread functions of the objects via radial filtering. The absolute magnitudes of the components of the HIP 3678 system are derived with the measured apparent magnitudes, adopting a distance of 504 ± 20 pc. The obtained \(J - K\)-colours and absolute magnitudes of the components are listed in Table 3. The colours are converted in the CIT photometric system (Elias et al. 1983), using the transformations equations from Carpenter (2001).

With a mass of 0.84 \(M_\odot\) for the white dwarf HIP 3678 A, as derived by Koesterke et al. (1998), we expect a mass of its progenitor star of about 4.3 \(M_\odot\), using the initial to final mass relationship of white dwarf from Catalán et al. (2008). This yields a main-sequence lifetime of the progenitor star of about 260 Myr (assuming a mass–luminosity relation of \(L \propto M^{3.5}\)). Due to the short cooling age of the white dwarf of only about 6600 yr, as derived by Ali et al. (2012), the derived age of the progenitor star also corresponds to the total age of the HIP 3678 system, assuming that the HIP 3678 A, B & C are coeval. In the colour–magnitude diagram in Fig. 3, we show the colours and absolute magnitudes of all components of the HIP 3678 system together with the log(age[yr]) = 8.4 isochrone of the evolutionary models of low-mass star from Baraffe et al. (1998).

While HIP 3678 A appears significantly bluer than a main-sequence star of the same absolute magnitude, as it is expected for a young and hot white dwarf, the photometry of the two co-moving companions HIP 3678 B and C agrees well with the expected colours and magnitudes of low-mass stars with an age of 260 Myr, which are located at the distance of the HIP 3678 system. Hence, the companionship of both co-moving companions to HIP 3678 A is well supported by photometry. By assuming a system age of 260 Myr, we can derive the masses of HIP 3678 B and C using the determined absolute magnitudes of the co-moving companions and the Baraffe et al. (1998) evolutionary models, which yield a mass of 0.85 ± 0.11 \(M_\odot\) for HIP 3678 B and 0.098 ± 0.024 \(M_\odot\) for HIP 3678 C, respectively. Furthermore, the spectral types of the detected companions can be approximated using the magnitude–spectral-type relation from Reid et al. (2004). According to this relation, we expect that HIP 3678 B is an early to mid-K dwarf (K2–K5), while HIP 3678 C is a mid-M dwarf with a spectral type in the range between M5 and M6.

### Table 3. The measured apparent photometry of all components of the HIP 3678 system. The absolute photometry of the components are derived with the apparent photometry of the objects and with the distance of the central star of the planetary nebula NGC 246. The \(J - K\)-colour of all objects is given in the CIT photometric system.

| Object | \(J\) (mag) | \(H\) (mag) | \(K_s\) (mag) |
|--------|-------------|-------------|--------------|
| HIP 3678 A | 12.81 ± 0.02 | 12.90 ± 0.02 | 12.90 ± 0.03 |
| HIP 3678 B | 13.07 ± 0.02 | 12.62 ± 0.02 | 12.46 ± 0.03 |
| HIP 3678 C | 18.44 ± 0.05 | 17.94 ± 0.06 | 17.53 ± 0.05 |

\(J - K\) | \(M_J\) (mag) | \(M_H\) (mag) | \(M_{K_S}\) (mag) |
|---------|-------------|-------------|--------------|
| -0.07 ± 0.04 | 4.3 ± 0.8 | 4.4 ± 0.8 | 4.4 ± 0.8 |
| 0.60 ± 0.04 | 4.6 ± 0.8 | 4.1 ± 0.8 | 3.9 ± 0.8 |
| 0.87 ± 0.08 | 9.9 ± 0.8 | 9.4 ± 0.8 | 9.0 ± 0.8 |

5 DETECTION LIMITS AND FURTHER COMPANIONS OF THE HIP 3678 SYSTEM

Among all imaging data presented in this work, the NACO \(K_s\) observations from 2004 exhibit the highest contrast. The achieved (S/N = 3) detection limit versus angular and projected separation is illustrated in Fig. 4.

Beside HIP 3678 B & C, no additional companion-candidates could be detected in this observing epoch within the fully covered field of view, i.e. at angular separations smaller than 6 arcsec (~3000 au of projected separation) around HIP 3678 A. In the background noise limited region a (S/N = 3) detection limit\(^4\) of about 20 mag is reached at angular separations from HIP 3678 A beyond about 0.5 arcsec. At the derived age of the HIP 3678 system of about 260 Myr, this allows the detection of low-mass sub-stellar companions with masses down to 36 \(M_{\text{jup}}\) and projected separations from HIP 3678 A of more than about 250 au. All stellar companions (mass > 75 \(M_{\text{jup}}\)) of HIP 3678 A can be detected at angular separations larger than 0.26 arcsec (~130 au of projected separation).

The NACO observations from 2007 were taken with the S27 optics and fully cover a field of view around HIP 3678 A with an angular radius of 11 arcsec (~5500 au of projected separation). Also in this larger field of view, no additional companions of HIP 3678 A are detected. Due to worse weather conditions, these imaging data are about 0.5 mag less sensitive than the ones taken in 2004, but the achieved contrast is sufficiently high so that additional stellar companions of HIP 3678 A could be detected.

\(^3\)2MASSJ 23233432-1521094: \(J = 11.851 ± 0.021\) mag, \(H = 11.558 ± 0.024\) mag, and \(K_s = 11.507 ± 0.025\)

\(^4\)Choice of S/N = 3, confirmed by inserting and retrieving simulated companions at this contrast level, see (Haase 2009).
The achieved (S/N = 3) detection limit of the NACO $K_s$-band observation taken in 2004, plotted versus angular (below) and projected (top) separation to HIP 3678 A. A limiting magnitude of about 20 mag is reached in the background-limited region beyond 0.5 arcsec, where brown dwarf companions with masses down to 36 $M_{\text{Jup}}$ can be detected with projected separations to HIP 3678 A of more than about 250 au. Beside the two comoving companion HIP 3678 B and C, additional stellar companions of HIP 3678 A can be excluded with projected separation larger than 130 au up to the field of view, fully covered by the NACO observation (angular separations of up to 6 arcsec or about 3000 au of projected separation).

6 RESULTS AND DISCUSSION

In the course of our multiplicity study of B stars, we have analysed near-infrared and visual imaging data taken with NACO/VLT and WFPC2/HST of HIP 3678 A, the central star of the planetary nebula NGC 246. The individual data were taken from the ESO and HST data-archives, and were combined with data points from the literature and from the 2MASS-PSC. In the high-contrast NACO, as well as in the HST data of lower resolution, we detected a new companion of HIP 3678 A, which clearly shares a common proper motion with its primary star. The new companion HIP 3678 C is located north-east of HIP 3678 A at an angular separation of about 1 arcsec (∼500 au of projected separation). With its previously known comoving companion, this detection makes the central star of the planetary nebula an hierarchical triple system, composed of the close binary system HIP 3678 AC and its wider companion HIP 3678 B at a projected separation of about 1900 au (∼3.9 arcsec). As described in the literature HIP 3678 A exhibits a mass of about 0.84 $M_{\odot}$ as derived from its effective temperature and luminosity using evolutionary models of young white dwarfs. With the initial to final mass relation of white dwarfs from Catalán et al. (2008), this yields an initial mass of the progenitor star of HIP 3678 A of about 4.3 $M_{\odot}$. Due to the short dynamical age of the planetary nebula NGC 246 of about only 6600 yr, as described in the literature, the age of the HIP 3678 system can be approximated to correspond to the main-sequence lifetime of the white dwarf progenitor star of about 260 Myr. The obtained apparent photometry of the co-moving companions HIP 3678B & C agrees well with low-mass stellar companions with the same age, as derived for HIP 3678 A, being located at the distance of the white dwarf. According to the Baraffe et al. (1998), evolutionary models HIP 3678 B and C exhibit masses of about 0.85 and 0.1 $M_{\odot}$, respectively. Using the absolute magnitude–spectral-type relation from Reid et al. (2004), we expect that HIP 3678 B is an early to mid-K dwarf, while HIP 3678 C is a M5 to M6 dwarf.

With the NACO high-contrast imaging observations, additional stellar companions of the white dwarf can be ruled out around HIP 3678 A at projected separations in the range between 130 and up to 5500 au. The same holds for brown dwarf companions with masses down to about 36 $M_{\text{Jup}}$ at projected separations beyond about 500 up to 3000 au, and down to 36 $M_{\text{Jup}}$ in the range of separation between 3000 and up to 5000 au.

The HIP 3678 is an evolved stellar system, which underwent a significant mass-loss of its primary component. Assuming conservation of angular momentum, e.g. due to radial symmetric mass-loss during the post main-sequence lifetime of the white dwarf progenitor star and the formation phase of the planetary nebula, we can approximate the initial separations of the components to HIP 3678 A. The total mass of the system decrease from about 5.2 to 1.8 $M_{\odot}$, which yields an expansion factor of the HIP 3678 system of about three. Hence, the system was significantly smaller in its initial configuration, but clearly wider than about 100 au. Due to the wide initial separation of the HIP 3678 AC binary, a common envelope phase of the evolved white dwarf progenitor star and its M dwarf companion during the asymptotic giant branch phase of the star can most probably be ruled out.

So far, about 40 close binaries could be detected as central stars of planetary nebulae all, which exhibit orbital periods of up to only a few days, mostly detected by periodic photometric variability or excess emission in the near-infrared (see De Marco et al. 2013, De Marco 2014, and references therein). Wider binaries with periods of more than 1000 d could be detected in the centre of planetary nebulae via radial velocity measurements (see e.g. van Winckel et al. 2014). In addition to these close stellar systems, only a few planetary nebulae are known, which harbour binary systems in their centres with wider separations of a few hundreds up to many thousands au, i.e. with orbital periods of more than 1000 yr. The main survey for such wide systems was carried out with the HST (Ciardullo et al. 1999). More recently further wide binaries in the centre of planetary nebulae could be identified, e.g. by Benetti et al. (2003), or most recently by Liebert et al. (2013). Among these nebulae, there are also two with possible triples in their centre, namely Abell 63 and NGC 7008. However, the triple nature of the central stars of these nebulae needs confirmation via follow-up high-contrast imaging observations and astrometry. Hence, the detection of HIP 3678 C, reported here, makes NGC 246 the first known planetary nebula with a confirmed hierarchical triple stellar system in its centre.

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