Composite Spectra, Paper XXIII: HD 69479/80,
a 90-day binary with a cool-giant primary

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HD 69479/80 is a composite-spectrum binary whose components are a late-G giant and an early-A dwarf. The orbit has a period of only 91 days (which seems short for a system containing a cool giant with a radius of ∼13 solar radii), and a very small, but probably significantly non-zero, eccentricity. We separated the component spectra by a procedure of spectral subtraction, using a standard single giant spectrum as a template, and found the closest match to the spectrum of the cool component to be that of 15 Cyg (G8 III). We measured the radial velocity of the secondary component from each uncovered spectrum, solved the SB2 orbit for the system, and derived a mass ratio $m_1 / m_2$ of 1.318. Fitting synthetic spectra to the spectra of the secondary component indicated a $T_{\text{eff}}$ of 9250 K, $\log g = 3.75$, and a rotational velocity of $\sim 90$ km s$^{-1}$. We determined the difference in absolute magnitude, $\delta V$, between the component stars to be 1.07 mag, the late-type component being the brighter; we could hence calculate radii and luminosities for both components, plot their H–R diagram positions, and fit evolutionary tracks. The best-fitting tracks indicated masses of 2.9 $M_\odot$ for the giant and 2.2 $M_\odot$ for the dwarf, which was fully in keeping with the mass ratio given by the SB2 orbit. The track for the dwarf star confirms that this component has begun to evolve away from the ZAMS. Fitting the corresponding isochrone to those H–R diagram positions indicated a log (age) of the system of approximately 8.60 Gyr since the cool star evolved from the ZAMS, which is a little younger than the ages deduced for many cool giants. We also detected the $\lambda$6707–Å lithium line in the spectrum of the giant component, thus adding to the evidence that it is near the start of its primary ascent of the red-giant branch.

1 Introduction and History

HD 69479/80 is a 6.5-mag star in the constellation Hydra, about 10° following Procyon. The cool component of the system is dominant in the red and the hot component in the violet, so both spectra are seen in the near-UV and blue regions. The composite nature of the object was first recognized almost 100 years ago by Cannon & Pickering (1924), who assigned it two numbers in the Henry Draper Catalogue, HD 69479 (type G0) and 69480 (A2). It has a $V$ magnitude of 6.53 (Corben, 1971), just marginally fainter than the formal 6.50 mag limit for the Bright Star Catalogue (Hoffleit, 1982). Efforts at assigning spectral types to the component stars have generally agreed that the secondary is an early A-type dwarf, but were somewhat less unified as regards the giant component (see Table 1). Even quite recently some catalogues have treated HD 69479/80 as a single star; the Hipparcos catalogue, for example, assigns a single number to the object.

Table 1  Previous classifications of HD 69479/80

| Reference         | Giant | Dwarf | Notes          |
|-------------------|-------|-------|----------------|
| Cannon & Pickering (1924) | G0    | A2    | 1              |
| Adams et al. (1935)  | dF8   |       | 2              |
| Markowicz (1969)    | G5 III| A2 V: |                |
| Olsen (1979)        | eF6   | Ap    | 3              |
| Eggen (1986)        | K0 III| A2 V  | 4              |
| Houk & Swift (1999) | K0III–IV| A2 V | 5              |
| Ginestet et al. (1997) | G7III− |       | 6              |
| Ginestet et al. (2002) | G7III−| A2 (IV:) | 7a           |
    | loc. cit.         | G9:III–IV| A2 V | 7b              |

Notes:
1. HD classification
2. Also called “Composite”. $M_V = +3.6$
3. From Strömgren indices
4. $(B - V) = 0.61$ mag; cf. $(B - V) = 0.63$ from Hipparcos
5. Prism spectra (Michigan re-classification programme)
6. Near-IR classification (prism) spectra
7a. $\Delta M_V = 0.65$ mag
7b. Model, using the parallax and $(B - V)$ from Hipparcos
The spectroscopic model prepared by Ginestet & Carquillat (2002) was based on a distance modulus of 7.47 mag derived from the Hipparcos parallax of 3.22 ± 0.6 mas. It yielded an absolute magnitude for the system of −0.27 mag, which could be considered a little high, given the absence of evidence of raised luminosity; see Table 7, a combined \((B - V)\) of 0.55 mag, individual absolute magnitudes of 0.0 mag for the giant and +0.8 mag for the dwarf, and individual \((B - V)\) values of 0.91 mag (giant) and 0.05 mag (dwarf). Comparison with the Hipparcos \((B - V)\) of 0.63 mag indicated a reddening \(E_{(B-V)}\) of 0.08 mag, or an extinction \(A_V\) of 0.28 mag, which is in keeping with the distance of 311 ± 64 pc indicated by the Hipparcos parallax.

This present analysis is based on a parallax of 4.368 ± 0.07 mas measured by Gaia (Gaia DR-2, 2018), which indicates a distance modulus of 7.08 mag; the corresponding observed absolute magnitude \(M_V\) of −0.27 mag can be considered more characteristic of a system containing a modest late-type giant and an early-type dwarf (see Section 5.1 and Table 7). Since the star is therefore now thought to be 36% nearer and correspondingly less luminous, the stellar parameters need to be revised downwards (see Section 5.2). Appeal to the semi-empirical three-dimensional model of Galactic interstellar extinction (Arenou, Grenon & Gomez 1992) suggests that the amount of extinction at the position and distance (229 pc) of HD 69479/80 is small: \(A_V = 0.09\) mag, or a reddening \(E_{(B-V)} = 0.03\) mag.

2 Radial Velocities and Orbit of the Cool Star

On the basis of unpublished Mt. Wilson radial velocities, Hynek (1938) had suggested that the radial velocity of HD 69479/80 is variable. In a major and very public-spirited effort, Abt (1970, 1973) listed the radial velocities, measured from about 23,000 Mt. Wilson plates, that had been published previously only as mean values for the stars concerned. In the case of HD 69479/80 there were four velocities, all obtained in the year 1925 and having a range as great as 37 km s\(^{-1}\), thus offering strong confirmation of its binary nature. Other publications are scarce; Duffet et al. (1993) listed a mean of 0 km s\(^{-1}\) for the system, derived from four individual plates, but did not give dates.

It was because of the reported composite nature of the spectrum that HD 69479/80 was placed on the Cambridge radial-velocity (RV) programme in 1978. In the following year the velocity was seen to have changed by 32 km s\(^{-1}\), and from then on it has been measured routinely. Griffin (1991) published orbital elements for the late-type component of the binary, though without listing the data or undertaking any discussion. Although both spectra are visible in the mid-blue, the RV spectrometers used here were optimised for observing cool-star spectra, and thus did not detect useable signals from the hot star. The RVs referred to here are therefore those of the cool component alone, and yielded an SB1 orbit (see Table 2).

119 RV observations with full metadata have now been measured for the cool component. They are set out in Table 3: 115 of our own observations and the four from Mt. Wilson published by Abt (1970). Of our own observations, most (38) of the early ones were measured with the original photoelectric spectrometer (Griffin, 1967) on the Cambridge 36-inch reflector; 31 others were obtained on a guest-investigator basis by RFG with the Haute-Provence (OHP) Coravel (Baranne, Mayor & Poncet, 1979) four with the analogous instrument at ESO, three with the RV spectrometer (Fletcher et al., 1982) on the 48-inch Dominion Astrophysical Observatory (DAO) telescope, and one with the Palomar RV spectrometer (Griffin & Gunn, 1974). Nearly all (38) of the observations obtained since 1997 have been made at Cambridge with an RV spectrometer based on the Coravel design.

The RVs measured at OHP and ESO (and reduced by Geneva’s own software) have been adjusted by adding 0.8 km s\(^{-1}\), an amount determined empirically to represent the systematic difference between the Geneva and the Cambridge scales. (That step is justified, since the OHP measurements had been subject to an undisclosed colour-dependent zero-point correction applied at source.) This adjustment has been made to all the relevant observations prior to their entry in Table 3.

To bring the weighted residuals from the SB1 solution into tolerable equality, the new Coravel observations have been weighted by 1.0, those from OHP and Palomar by 0.5, those from the original spectrometer, ESO and the DAO by 0.25, and the old Mt. Wilson observations by 0.015. The resulting orbital elements are listed in Table 2 where they are compared to the elements published by Griffin (1990). While the new values of the elements are little changed, their precisions are substantially tighter by virtue of the methodology of the new Cambridge Coravel. We have added to Table 3 the phases and residuals of the observations as given by the orbit solution in Table 2.

3 Spectroscopy of HD 69479/80

An exploratory photographic spectrometer of the star was obtained at 10 Å mm\(^{-1}\) at the coudé focus of the Mt. Wilson 100-inch telescope in 1981. It at once revealed the composite nature of the object: a somewhat rotationally broadened Ca ii K line typical of an early-A star, amid a crowd of narrow lines characteristic of a cool giant. Beginning in 2000, the system was monitored at the coudé focus of the 1.2-m DAO telescope and 96-inch spectrograph, with a resolving power of
**Table 3**  Radial-velocity observations of the cool giant component of HD 69479/80.

Except as noted, the observations were made with the large spectrometer at Cambridge (weight 0.25) in 1978–1990, with the Haute-Provence Coravel (weight 0.5) in 1991–1998, and with the Cambridge Coravel (weight 1) in 1998–2017.

| Date (UT) | MJD  | Velocity (km s⁻¹) | Phase (O−C) (km s⁻¹) |
|-----------|------|-------------------|---------------------|
| 1925 Jan. 11.46† | 24161.46 | +11.9 | 771.980 | -1.1 |
| Apr. 2.23† | 24223.74 | +7.4 | 737.969 | +0.7 |
| May 1.15† | 271.15 | -1.8 | 777.187 | -3.7 |
| Nov. 25.54† | 479.34 | -20.1 | 779.481 | +4.0 |
| 1978 Mar. 29.89 | 43596.89 | +11.8 | 0.931 | +0.6 |
| Oct. 12.20 | 793.20 | +0.7 | 3.092 | -0.6 |
| 1979 Nov. 25.19 | 44202.19 | -23.0 | 7.594 | -1.6 |
| Dec. 31.06 | 2388.06 | +12.5 | 0.989 | -0.6 |
| 1980 Mar. 9.30 | 43407.93 | -6.0 | 8.758 | -0.8 |
| Dec. 7.14 | 580.14 | -4.9 | 11.755 | +0.7 |
| 1981 Jan. 15.04 | 44619.04 | +2.7 | 12.183 | +0.4 |
| Feb. 2.04 | 637.04 | -18.6 | 0.381 | +0.5 |
| Mar. 12.95 | 675.95 | +1.1 | 8.099 | +0.6 |
| Apr. 14.87 | 708.87 | +4.4 | 13.172 | +0.9 |
| 17.87 | 711.87 | +0.8 | 0.205 | +0.9 |
| 27.87 | 721.87 | -10.8 | 0.315 | +1.9 |
| May 18.15† | 742.15 | -24.0 | 0.538 | -0.2 |
| 1982 Jan. 10.05 | 44979.05 | +6.6 | 16.146 | +0.5 |
| Mar. 4.90 | 45032.90 | -6.1 | 0.739 | +1.4 |
| 12.89 | 040.89 | +3.3 | 0.827 | +0.7 |
| 1983 Dec. 1.10 | 45669.10 | -7.6 | 23.742 | -0.5 |
| 1984 Feb. 8.97 | 53758.97 | -24.2 | 24.512 | 0.0 |
| 1985 Jan. 1.10 | 46066.10 | +8.1 | 22.813 | -0.8 |
| 29.01 | 094.01 | -22.0 | 420.0 | -0.2 |
| Nov. 12.20 | 381.20 | -23.1 | 51.981 | -1.0 |
| 1986 Jan. 26.02 | 46456.02 | -20.7 | 32.405 | +0.1 |
| Mar. 5.94 | 494.94 | +3.6 | 0.833 | +0.3 |
| Apr. 4.84† | 524.84 | +3.2 | 14.103 | +0.0 |
| Oct. 26.20 | 729.20 | -20.9 | 35.412 | +0.4 |
| Dec. 12.15 | 776.13 | +10.3 | 0.992 | -0.8 |
| 1987 Jan. 31.02 | 46826.02 | -24.7 | 36.478 | -0.7 |
| Feb. 28.94 | 584.94 | -0.6 | 0.796 | +0.2 |
| Oct. 18.21† | 47086.21 | -15.0 | 39.342 | +0.6 |
| Nov. 7.39† | 106.39 | -24.2 | 0.565 | -1.3 |
| 1988 Jan. 25.45† | 47185.45 | -23.4 | 40.435 | -0.8 |
| Feb. 1.37† | 192.37 | -24.3 | 511.0 | -0.1 |
| Mar. 11.93† | 231.93 | +1.7 | 0.946 | +0.3 |
| Nov. 7.10† | 472.10 | -21.4 | 43.591 | +0.2 |
| Dec. 13.10 | 508.10 | +13.1 | 0.987 | 0.0 |
| 20.09 | 515.09 | +12.2 | 44.064 | +0.4 |
| 1989 Jan. 5.15 | 47531.15 | -3.7 | 4.240 | +0.5 |
| Jan. 18.00 | 544.00 | -17.2 | 0.382 | +1.9 |
| 1990 Jan. 14.04 | 47905.04 | -18.1 | 48.356 | -1.2 |
| 1991 Jan. 25.98 | 48281.98 | -24.4 | 52.506 | -0.2 |
| 1993 Feb. 12.02 | 49030.02 | -16.6 | 51.353 | 0.0 |
| 1995 Jan. 2.12 | 49719.12 | -16.8 | 51.246 | +0.8 |
| 1996 Mar. 30.90 | 50172.90 | -31.0 | 922.02 | -1.2 |
| 1997 Jan. 26.10 | 50474.10 | -31.8 | 922.02 | -1.2 |
| 1998 May 1.15 | 50931.15 | -18.5 | 88.878 | +0.3 |
| 1999 Dec. 29.14 | 51541.14 | -18.5 | 88.878 | +0.3 |
| 2000 Feb. 12.02 | 51586.02 | +7.8 | 88.878 | +0.3 |
| Mar. 1.96 | 604.96 | +10.7 | 89.086 | 0.0 |
| Nov. 20.21 | 868.21 | +12.9 | 91.984 | -0.1 |

Sources of observations:

- *Mt. Wilson 60-inch telescope; wt. 0.015*
- †Palomar 200-inch telescope; wt. 0.5
- ‡HFP Coravel; wt. 0.5
- †ESO Coravel; wt. 0.25
- ‡DAO 48-inch telescope; wt. 0.25
- ‡Original Cambridge spectrometer; wt. 0.25
- **Cambridge Coravel; wt. 1.0**
Table 4  Spectroscopic observations of HD 69480, including the orbital phases and RVs of the giant component (RV\textsubscript{G}) computed for the same dates and times, and our measurements of the RVs of the secondary component (RV\textsubscript{A}); the zero-point adjustments described in Sect. 5 have been made. The residuals in the final column are with respect to the orbit solution reproduced in Fig. 2 and Table 5.

| Observation ID | Date (UT) | MJD   | Nominal RV\textsubscript{G} (\AA) | Phase (O - C) | RV\textsubscript{A} (km s\(^{-1}\)) | (O - C) |
|----------------|-----------|-------|-----------------------------------|--------------|-----------------------------------|---------|
| DAO 15845/6   | 2000 Nov. 11.54 | 51859.54 | 4481 | 8.4 | .888 | -21.0 | +3.1 |
| DAO 15074     | 2000 Nov. 14.58 | 51862.58 | 4481 | 10.7 | .922 | -24.2 | +3.0 |
| DAO 16115     | 2000 Nov. 16.53 | 51864.53 | 4481 | 11.9 | .943 | -28.1 | +0.6 |
| DAO 16117     | 2000 Nov. 16.57 | 51864.57 | 3933 | 11.8 | .944 | -32.1 | +3.4 |
| DAO 2985      | 2002 Mar. 25.24 | 52058.24 | 4481 | -18.9 | .378 | 8.2 | -3.5 |
| DAO 3193      | 2002 Mar. 29.18 | 52062.58 | 4481 | 10.7 | .922 | -24.2 | +3.0 |
| DAO 2002 May 16.53 | 51864.53 | 4481 | 11.9 | .943 | -28.1 | +0.6 |
| DAO 2002 May 16.57 | 51864.57 | 3933 | 11.8 | .944 | -32.1 | +3.4 |
| DAO 2985      | 2002 Mar. 25.24 | 52058.24 | 4481 | -18.9 | .378 | 8.2 | -3.5 |
| DAO 2002 May 16.53 | 51864.53 | 4481 | 11.9 | .943 | -28.1 | +0.6 |
| DAO 2002 May 16.57 | 51864.57 | 3933 | 11.8 | .944 | -32.1 | +3.4 |
| DAO 2985      | 2002 Mar. 25.24 | 52058.24 | 4481 | -18.9 | .378 | 8.2 | -3.5 |
| DAO 2002 May 16.53 | 51864.53 | 4481 | 11.9 | .943 | -28.1 | +0.6 |
| DAO 2002 May 16.57 | 51864.57 | 3933 | 11.8 | .944 | -32.1 | +3.4 |
| DAO 2985      | 2002 Mar. 25.24 | 52058.24 | 4481 | -18.9 | .378 | 8.2 | -3.5 |
| DAO 2002 May 16.53 | 51864.53 | 4481 | 11.9 | .943 | -28.1 | +0.6 |
| DAO 2002 May 16.57 | 51864.57 | 3933 | 11.8 | .944 | -32.1 | +3.4 |

*Low S/N; zero-weighted in the orbit solution.


3.1 Uncovering the spectrum of the hot component

To separate the superimposed spectra of these binaries we adopt a technique of point-by-point subtraction. By appealing to trial and error methods we determine the best match to the spectrum of the primary from among a library of cool-giant spectra. A good match is indicated when there are very few (preferably no) residual artefacts ('spikes') in the secondary's spectrum caused by mis-matches in strength or profile (width) between the giant's spectrum lines and those of the surrogate. Note that it is highly important to align the spectra of the giant component and of the standard giant precisely in wavelength to avoid the creation of unwanted artefacts in the residue arising from small discrepancies between wavelength scales. To that end, we routinely cross-correlate the entire secondary's spectrum with the synthetic spectrum described above and broadened to match the line-widths of the secondary star. Since the composite spectra were extracted in the rest-frame of the giant component (as just explained), the RVs measured for the secondary needed to be corrected for the RV of the giant on the date of each observation (column 5 of Table 4), as determined from the SB1 orbit (Table 2).

The observations of the H$\delta$ region were helpful for determining the $T_{\text{eff}}$ of the uncovered secondary star, but H$\delta$ was the only measureable feature in that region and we could not determine reliable RV measurements from it, so we have not included those observations in Table 4.

RV measurements of the spectrum of the early-A star (HD 69480) are difficult to make very accurately. Not only do early-A stars have rather few spectral lines even in the near-UV, but this A-type star is also rotating by about 90 km s$^{-1}$, causing its lines to be broad and shallow and making the weaker ones too indistinct to measure well – or even to detect with much certainty. The only prominent lines in the near-UV region that we observed were two Balmer lines ($H\alpha$ at $\lambda$ 3970 Å and H$\delta$ at $\lambda$ 3889 Å) and the Ca $\text{II}$ $K$ and $H$ lines at $\lambda$ 3933 and 3968 Å. The Balmer lines are intrinsically wide and therefore not well suited for RV measurements; moreover, H$\delta$ is right at the short-wavelength end of our spectra, where the stellar flux gradients are changing rapidly owing (largely) to atmospheric transparency and the CCD response, while H$\alpha$ is closely blended with the Ca $\text{II}$ $H$ line and is consequently additionally complicated by whatever asymmetries affect the $K$ line.

We experimented with cross-correlating the entire length of each near-UV spectrum of HD 69480, but concluded that the most consistent set of measurements were those that involved just the $K$ line. We carried out similar trials with various sub-sets of lines in the blue region; however, since the signal in the observed spectrum had been reduced to about only 35% of the original level by our subtracting away the contribution of the giant, the noise level in the secondary spectra was inevitably raised, and the most reliable cross-correlation signals were obtained when the wavelength

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Table 2  
SB1 orbit solution for the giant component

| Parameter | Griffin (1990) | This paper |
|-----------|---------------|------------|
| $P$ (days) | 90.836 ± 0.006 | 90.8406 ± 0.0014 |
| $T$ (MJD) | 46147.12 ± 0.12 | 51143 ± 0.9 |
| $\gamma$ (km s$^{-1}$) | −5.52 ±0.10 | −5.65 ± 0.05 |
| $K$ (km s$^{-1}$) | 18.77 ± 0.14 | 18.72 ± 0.07 |
| $e$ | 0 | 0.0060 ± 0.0035 |
| $\omega$ | − | 359 ± 36 |
| $a \sin i$ (Gm) | 23.44 ± 0.18 | 23.38 ± 0.09 |
| $f(m)$ (M$_\odot$) | 0.0624 ± 0.0014 | 0.0619 ± 0.0007 |
| R.m.s. residual (wt. 1) | 0.7 | 0.37 km s$^{-1}$ |

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4 RVs of the Secondary Star, and a Double-Lined Orbit

We measured the RVs of the secondary star by cross-correlating each extracted spectrum with the synthetic spectrum described above and broadened to match the line-widths of the secondary star. Since the composite spectra were extracted in the rest-frame of the giant component (as just explained), the RVs measured for the secondary needed to be corrected for the RV of the giant on the date of each observation (column 5 of Table 4), as determined from the SB1 orbit (Table 2).

The observations of the H$\delta$ region were helpful for determining the $T_{\text{eff}}$ of the uncovered secondary star, but H$\delta$ was the only measureable feature in that region and we could not determine reliable RV measurements from it, so we have not included those observations in Table 4.

RV measurements of the spectrum of the early-A star (HD 69480) are difficult to make very accurately. Not only do early-A stars have rather few spectral lines even in the near-UV, but this A-type star is also rotating by about 90 km s$^{-1}$, causing its lines to be broad and shallow and making the weaker ones too indistinct to measure well – or even to detect with much certainty. The only prominent lines in the near-UV region that we observed were two Balmer lines ($H\alpha$ at $\lambda$ 3970 Å and H$\delta$ at $\lambda$ 3889 Å) and the Ca $\text{II}$ $K$ and $H$ lines at $\lambda$ 3933 and 3968 Å. The Balmer lines are intrinsically wide and therefore not well suited for RV measurements; moreover, H$\delta$ is right at the short-wavelength end of our spectra, where the stellar flux gradients are changing rapidly owing (largely) to atmospheric transparency and the CCD response, while H$\alpha$ is closely blended with the Ca $\text{II}$ $H$ line and is consequently additionally complicated by whatever asymmetries affect the $K$ line.

We experimented with cross-correlating the entire length of each near-UV spectrum of HD 69480, but concluded that the most consistent set of measurements were those that involved just the $K$ line. We carried out similar trials with various sub-sets of lines in the blue region; however, since the signal in the observed spectrum had been reduced to about only 35% of the original level by our subtracting away the contribution of the giant, the noise level in the secondary spectra was inevitably raised, and the most reliable cross-correlation signals were obtained when the wavelength

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[1] http://www.physics.appstate.edu/spectrum/spectrum.html
Fig. 1 Uncovering the spectrum of HD 69480. When the spectrum of the G8III standard 15 Cyg (panel a) is subtracted optimally from one of the composite spectra (panel b), the spectrum of the A2-type secondary (HD 69480) is revealed (panel c). It is compared in panel d with a synthetic spectrum calculated for $T_{\text{eff}} = 9250\,\text{K}$ and $\log g = 3.75$, and blurred to mimic a rotational velocity of $90\,\text{km\,s}^{-1}$.

region was limited to the Mg II $\lambda$ 4481 Å line. The RVs thus derived (and recorded in Table 4) could consequently be affected by individual systematic errors, which we attempted to minimise by obtaining a substantial number of observations, many in sequential pairs with the intention of increasing the S/N levels of the spectra by co-adding them. Unfortunately, because the star is a winter object and at a declination of only $+4^\circ$, favourable observing conditions for it in the winter climate of Victoria are not very plentiful.

At its distance of 229 pc (Section 1), HD 69479/80 could show weak interstellar (IS) absorption, though we found no clear evidence of it. IS features can be detected best in early-type stars, whether or not rotating. In composite-spectrum systems, IS K lines have readily been detected and measured in the uncovered spectra of a hot secondary if its spectral type is earlier than A3; examples are HD 4615 (Griffin & Griffin, 1999, Fig. 3); HR 233 and 36 Tau (Mason et al., 1997, Figs. 5 & 7). In the case of HD 69479/80 the secondary’s K line is strong enough, and therefore broad enough, to mask a weak IS line; furthermore (as already explained) the S/N ratios in our near-UV spectra were rather low, and we did not identify any features that could definitely be attributable to IS absorption and not to random noise spikes. As mentioned in Section 1, the amount of IS absorption calculated for this system from a semi-empirical model is small, and our deduction via a quite different route (see Table 7) confirms that finding.

We combined our measured RVs of the secondary star with those of the primary as recorded in Table 3, to derive the SB2 orbit for the system. It is illustrated in Fig. 2: the elements of the orbit are listed in Table 5. The caption of Fig. 2 links the various symbols to the sources of RVs for the primary component, or – in the case of the secondary component – to the respective wavelength region observed. As is our custom in these derivations of SB2 orbits, we applied a global weight of 0.02 to all the secondary velocities. Observations of the secondary that did not achieve a satisfactory level of exposure were zero weighted; they are plotted as open diamonds.

The secondary’s velocities exhibited a small systematic offset from the SB1 solution for the giant component, and a universal correction of $-3.0\,\text{km\,s}^{-1}$ was applied to all of the secondary’s RVs so as to minimize the residuals compared to those of the giant star. Those corrections have been applied to the RVs of the secondary prior to their entry in column 7 of Table 4. The residuals listed in the final column of that Table are with respect to our SB2 solution.

5 Parameters of the Component Stars
5.1 Photometric model

As a by-product, the subtraction procedure furnishes the ratio of the fluxes from the component stars at specified wavelength intervals. By selecting 50-Å bands centred on steps 25 Å wide we can make use of the
phometry of a range of bright stars of various luminosities published by Willstrop (1962). The goal is to find a pair of stars that resemble the binary components sufficiently well as to give a constant wavelength-independent fit to the ratios of their fluxes. Since Willstrop’s magnitudes were normalized in \( V \), the fraction of the published values required to match those of the binary yields the value of \( \Delta V \) between the two component stars. In this way we derived \( \Delta V = 1.07 \) mag for HD 69479/80.

The parallax of HD 69479/80, measured by Gaia DR-2 (2018) as 4.368 ± 0.070 mas, corresponds to a distance of 229 ± 4 pc and a distance modulus of 6.80 ± 0.04 mag. If \( m_V = 6.53 \) mag (Section 1), the absolute magnitude \( M_V \) of the system is –0.27 mag. The values of \( M_V \) for the component stars and their individual and combined (modelled) \((B - V)\) colours are listed in Table 7. The results for \((B - V)\) also support the thesis that there is only a very small amount of IS absorption affecting this system.

It is more than a little disconcerting that the Gaia parallax is so different from the Hipparcos one, which is listed as 3.22 ± 0.60 mas (van Leeuwen, 2007); the difference is almost twice the formal error of the Hipparcos value. One possible cause of erroneous parallax measurements in this system is a confusion between the orbital motion and the motion of the photocentre. That could be significant in this case because the orbital period is only 0.4 day shorter than a quarter of a year. The likelihood of interplay between the two orbits will depend on the cadence of the observations; measurements made only at the optimal times (i.e., at 6-monthly intervals) will have occurred at the same phases of the binary and will not have been affected by relative movements of the photocentre. Unfortunately, information regarding the dates of the observations was not readily available.

Comparing the modelled value of \((B - V)\) given in Table 7 with the Hipparcos one of 0.63 mag indicates \( E_{(B-V)} = 0.04 \) mag (i.e., \( A_v = 0.13 \)). Both that and the value given by Arenou et al.’s semi-empirical model suggest that interstellar absorption is not very significant for this system.

### 5.2 \( T_{\text{eff}} \) and luminosities

In these analyses we customarily adopt for the giant component the value of \( T_{\text{eff}} \) that has been derived for

| Star | Symbol | no. | Wt. | Source of velocity |
|------|--------|-----|-----|-------------------|
| Primary | Δ | 4 | 0.015 | Mt. Wilson (Abt 1970) |
| | ○ | 38 | 0.25 | Cambridge spectrometer |
| | + | 4 | 0.25 | ESO Coravel |
| | □ | 1 | 0.50 | Palomar |
| | ✗ | 3 | 0.25 | DAO 1.2-m telescope |
| | ● | 31 | 0.50 | OHP Coravel |
| | ■ | 38 | 1.0 | Cambridge Coravel |
| Secondary | ▲ | 25 | 0.1 | Ca II H & K region |
| | ★ | 15 | 0.1 | Mg II λ 4481 Å region |
| | ◇ | 6 | 0.0 | both regions |

| Table 5 | Orbital elements for HD 69479/80* |
|---------|----------------------------------|
| \( P \) (days) | = 90.841 ± 0.001 |
| \( T \) (MJD) | = 51052 ± 9 |
| \( \gamma \) (km s\(^{-1}\)) | = -5.64 ± 0.05 |
| \( K_1 \) (km s\(^{-1}\)) | = 18.72 ± 0.07 |
| \( K_2 \) (km s\(^{-1}\)) | = 24.6 ± 0.5 |
| \( q \) | = 1.316 ± 0.027 |
| \( e \) | = 0.006 ± 0.003 |
| \( \omega \) (degrees) | = 359 ± 35 |
| \( a_1 \sin i \) (Gm) | = 23.38 ± 0.08 |
| \( a_2 \sin i \) (Gm) | = 30.8 ± 0.6 |
| \( f(M_1) \) (M\( \odot \)) | = 0.062 ± 0.001 |
| \( f(M_2) \) (M\( \odot \)) | = 0.141 ± 0.008 |
| \( M_1 \sin^3 i \) (M\( \odot \)) | = 0.437 ± 0.021 |
| \( M_2 \sin^3 i \) (M\( \odot \)) | = 0.332 ± 0.008 |
| R.m.s. residual (wt. 1) (km s\(^{-1}\)) | = 0.36 |

*Subscripts 1 and 2 denote the primary and the secondary star, respectively.

### 5.2 \( T_{\text{eff}} \) and luminosities

In these analyses we customarily adopt for the giant component the value of \( T_{\text{eff}} \) that has been derived for...
Table 7  Physical parameters of the component stars of HD 69479/80

| Component Star | $M_V$ (mag) | $(B-V)$ (mag) | $T_{\text{eff}}$ (K) | BC (mag) | $M_{\text{bol}}$ (mag) | $R$ (R$_\odot$) | $\log L$ (L$_\odot$) | $M$ (M$_\odot$) |
|----------------|-------------|--------------|-------------------|--------|-------------------|-------------|----------------|----------------|
| Primary (G8 III) | 0.07 ± 0.04 | 0.95 ± 0.03 | 5050 ± 70 | −0.29 ± 0.03 | −0.22 ± 0.04 | 12.9 ± 0.4 | 1.98 ± 0.02 | 2.9 ± 0.1 |
| HD 69479 | 1.14 ± 0.04 | 0.03 ± 0.03 | 9250 ± 200 | −0.11 ± 0.03 | −0.04 ± 0.04 | 2.2 ± 0.1 | 1.48 ± 0.02 | 2.2 ± 0.1 |
| Secondary A2 IV | 0.07 ± 0.04 | 0.95 ± 0.03 | 5050 ± 70 | −0.29 ± 0.03 | −0.22 ± 0.04 | 12.9 ± 0.4 | 1.98 ± 0.02 | 2.9 ± 0.1 |
| HD 69480 | 1.14 ± 0.04 | 0.03 ± 0.03 | 9250 ± 200 | −0.11 ± 0.03 | −0.04 ± 0.04 | 2.2 ± 0.1 | 1.48 ± 0.02 | 2.2 ± 0.1 |
| System (modelled) | −0.27 ± 0.04 | 0.61 ± 0.03 | 5050 ± 70 | −0.29 ± 0.03 | −0.22 ± 0.04 | 12.9 ± 0.4 | 1.98 ± 0.02 | 2.9 ± 0.1 |
| (observed) | −0.27 ± 0.04 | 0.61 ± 0.03 | 5050 ± 70 | −0.29 ± 0.03 | −0.22 ± 0.04 | 12.9 ± 0.4 | 1.98 ± 0.02 | 2.9 ± 0.1 |

*Based on the Gaia DR-2 (2018) distance modulus of 6.80 ± 0.04 mag.

the star selected as the surrogate giant for the subtraction process, in this case 15 Cyg. The five independent published values listed in Table 6 point to a mean of 5050 K and an estimated precision of ± 70 K, so that was adopted for the giant component. A $T_{\text{eff}}$ of 9250 K for the secondary had already been determined by comparing its spectra with synthetic ones, as outlined in Section 3.1.

From the $T_{\text{eff}}$ and $M_V$ for both stars we calculated their luminosities, radii and $M_{\text{bol}}$. The results are recorded in Table 7.

5.3 Evolution and age

Evolutionary tracks, created by Pols et al. (1998), applied by Schröder, Pols & Eggleton (1997) and now available in the public domain, were fitted to the positions of the stars in the H–R diagram (see Fig. 3). The selected tracks (assuming solar abundances) fit the H–R positions of both stars quite decisively; they suggest strongly that the secondary has already commenced its evolution away from the main sequence, while the primary has apparently not yet commenced its first travel up the red-giant branch. The smallness of the error bars is brought about by the high precision quoted for the Gaia parallax. The values of the stellar masses given by the tracks are similarly tightly constrained, and their ratio (1.318) reflects closely the value of $q$ (1.316) determined by the SB2 solution (Table 5). Comparing these values for the masses with those given in Table 5 indicates that the inclination of the orbit is about 32°.

We then investigated the age of the component stars by finding the best-fitting isochrone from the library made available in the public domain by Pols et al. (1998) (see Fig. 4). The isochrone for log(age) of 8.60 fitted well to the H–R positions of both stars. We note that the age of this binary is not a great as has been found...
...for many other composite-spectrum binaries analysed in this series of papers.

![Graph](image_url)

**Fig. 5** The presence of Lithium $\lambda$ 6707 Å in the spectrum of HD 69479/80 (thick line), at the position of the arrow. The comparison spectrum (thin line) is that of o Leo.

If we now examine what this analysis shows regarding the evolutionary status of the giant primary component, and in particular how ‘normal’ it is, the following facts become relevant:

(a) The value of $\log (L_1)$ given in Table 7 is close to the value of $\sim 1.7$ listed by Schmidt-Kaler (1982) for a G8 III star but a little raised, as might be expected for a star that had only recently arrived at the foot of the red-giant branch.

(b) The system appears to be somewhat younger than is usually found for red giants that are more advanced along the RG branch.

(c) The system has a short enough period that the orbit might be expected to have reached full circularity (i.e., zero eccentricity). Instead, while the value of $e$ (Table 6) is small it is probably significantly non-zero.

(d) Strong evidence of youth is provided by the presence of a small but distinct feature at the position of the $\lambda$ 6707 Å Li I line. At those red wavelengths the observed spectrum of the binary is effectively that of the giant component alone. In order to confirm the identity of the Li feature, we compare in Fig. 5 the spectrum of HD 69479/80 with that of o Leo, which was found by Griffin (2002) to contain two metallic-line stars; again, only the cooler of the pair, having a spectral type of late Fm, is bright enough at those wavelengths to record a signal. It is uncommon to find Li I strong enough to be detected unambiguously in a class III giant later than mid-G, its presence mostly being restricted to supergiants and bright giants. Its appearance here definitely suggests that the giant star in this binary has evolved across the Herzsprung gap but has not yet fully undergone the upheavals, triggered by the onset of surface convection, that effectively dilute lithium beyond detection.

From the above we conclude that the giant component is only about to commence its first ascent of the red-giant branch, and is therefore well prior to commencing the more advanced phase of He-burning and convective dilution in its atmosphere. It is unusual that such a firm conclusion about the evolutionary status of a giant star can be deduced so unambiguously, and it stems very considerably from the high precision of Gaia data.

### 6 The Binary System HD 69479/80

Our analysis of HD 69479/80 has derived physical parameters for both component stars. Matching the H–R positions of the stars with standard evolutionary tracks has confirmed that the secondary has already left the ZAMS, as was suggested by its value of $\log g = 3.75$ (Fig. 1 and Section 3.1). The cool-giant primary is currently positioned near the low-luminosity portion of the red-giant branch, and the spectrum that best matched it (as judged from the relatively clean residues that resulted from the subtraction process described in Section 3.1) was that of the G8III standard 15 Cyg; accordingly that was the classification that we gave it. Deriving a high-precision SB2 orbit, and fitting to evolutionary tracks and isochrones, yielded a mass of 2.9 $M_\odot$ for the primary, 2.2 $M_\odot$ for the secondary (a mean mass ratio $q$ of 1.317), and an age for the system of 8.60 Gyr. During its evolution the system’s orbit has become almost circular, and the secondary (an early-A dwarf) has evolved away from the zero-age main-sequence even though its mass is only 75% of that of the cool giant. The giant component shows a weak lithium feature, which confirms our deduction that the star has not yet begun to ascend the red-giant branch.

However, possibly the most remarkable aspect of this binary is its lack of notable properties, rendering it highly important as a standard for analyses of other composite-spectrum binaries. Although it has a period of only 91 days, which Griffin (2011) demonstrated to be relatively short for a system containing a cool giant (in our on-going study of composite-spectrum binaries, only 20% of the G–K giants have periods smaller than 100 days) the giant in this binary shows no emission sequence even though its mass is only 75% of that of the cool giant. The giant component shows a weak lithium feature, which confirms our deduction that the star has not yet begun to ascend the red-giant branch.
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