Observations of binary stars by speckle interferometry – III

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Introduction

This is the third paper in a series describing observations of binary stars using the technique of speckle interferometry. The observations described here were made as part of a collaborative programme with members of the Chatterton Astronomy Department of Sydney University. All observations were made using the 3.9-m telescope of the Anglo-Australian Observatory. The classical Rayleigh diffraction limit for this telescope is 0.03 arcsec at a wavelength of 500 nm.

The results of 25 measurements of 21 objects are presented. The objects include long-period spectroscopic binaries from the 6th Catalogue of Batten (1968) and close visual binary systems from the 3rd Catalogue of Finsen & Worley (1970). Eight of the objects have not been previously resolved by speckle interferometry, and six of the objects are members of the Hyades cluster. These results are sufficiently accurate to demonstrate that past errors by visual observers cannot explain the apparent deviation of Hyades stars from the normal mass–luminosity relationship; however, if the distance modulus calculated by Hanson is assumed, it is not necessary to assume a separate relationship. γ Tau is resolved into two components for the first time.

Results

Observational techniques have been discussed by Morgan et al. (1978) and Morgan, Beckmann & Scaddan (1980) in previous papers in the series, and the data reduction procedure using an optical analogue technique has been described by Beddoes et al. (1976). The separations and position angles for 21 objects are listed in Table 1. There is an ambiguity of 180° in position angle which, where possible, has been removed by inspection of published visual elements. Where a standard epoch is quoted for an orbit the position angle residual includes the effect of precession from that date. The ‘quality’ of each result is a qualitative assessment of the error in the measurement of the separation based on the depth of the fringe modulation. An observation is graded quality ‘a’ if the formal error in the separation is less than ± 2 per cent, quality ‘b’ if the formal error lies between ± 2 and ± 4 per cent, ‘c’ if the error lies between
### Table 1. Observations of binary star systems.

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* Radial velocity variable.
† Effect of precession not included.

± 4 and ±10 per cent and ‘d’ if the error lies between ±10 and ±20 per cent. The error in position angle is typically ±2°. Mean residuals for separation and position angle are ±0.003 arcsec and −0.6° respectively, and root mean square residuals are 0.023 arcsec and 4.8°. It was pointed out in an earlier paper (Morgan et al. 1978) that the mean position angle residual for those observations (3°) indicated a possible systematic error in the data. It was eventually realised that there was a potential source of error of about this magnitude in the calibration procedure used when the interferometer was initially adjusted on the telescope. This source of error has now been eliminated. Whilst it is not possible to correct the earlier data, the mean position angle residual for observations reported here is taken as evidence of the correctness of the revised calibration procedure.

Notes

HD 3196   ADS 490   13 CET

This is a triple system comprising a visual binary (resolved here) of which the primary is itself spectroscopically resolved into two components. Residuals are derived from elements by: (a) Behall (1961) and (b) Gatewood & Behall (1975). Gatewood & Behall noted that the system appears to be overluminous according to the empirical mass–luminosity relation, and redefined the elements (together with the parallax) to confirm this. Both these observations and McAlister's (1978, 1979) interferometric results yield smaller residuals for the new elements (b), thus tending to confirm that the system is overluminous.

HD 8556   ADS 1123

ADS 1123 has been resolved both visually and spectroscopically. The residuals have been derived from elements by: (a) Van den Bos (1961), (b) Finsen (1973) and (c) Morby (1975). Morby’s elements are calculated by a method which combines both visual and spectroscopic results. Van den Bos noted that his visual elements appeared to be inconsistent with various radial velocity observations, but concluded that this may be due to a small error in the quoted date of periastron. Fletcher (1973) obtained spectroscopic elements which are similar to Van den Bos’ visual elements. The discrepancy between visual and spectroscopic
observations has also been extensively discussed by Ishida (1966). These observations, and those published by McAlister (1979) and by Blazit et al. (1977) give small residuals for all the sets of elements.

\[ -30^\circ 529 \]

This is a triple system comprising a pair of K3V stars, which has been resolved here, and a fainter companion lying some 1.4 arcsec away. Residuals derived from the elements suggested by Wieth-Knudsen (1956) are remarkably small considering that the system has completed more than ten orbits since the quoted periastron.

\[ \text{HD 16620} \quad \epsilon \text{CET} \]

This short-period binary (period less than three years) has been resolved both visually and spectroscopically. Residuals are derived from elements by: (a) Baize (1962) and (b) Finsen (1970). There is a large positive position angle residual, but this is consistent with observations reported by McAlister (1977a, 1978, 1979). Abt & Levy (1976) have derived a set of spectroscopic elements assuming the values of \( P, e \) and \( \omega \) from Baize's orbit.

\[ \text{HD 20121} \quad -44^\circ 1025 \]

This is at least a triple system. The observation reported here resolves the pair AB; star C is a physical companion at 3 arcsec, and Eggen (1965a) reports radial velocity variations indicating the presence of a fourth component. Residuals are calculated from elements by: (a) Wierzbinski (1958a) and (b) Eggen. In both cases the residuals are large. However, for both orbits the observation was very close to periastron passage, Wierzbinski quoting 1976.5 and Eggen 1979.5. This observation was made between the dates of the two periapses, and the sign of the position angle residual is different for the two orbits. Assuming, as a first-order approximation, that the size of the position angle residual is linearly related to the error in periastron for the corresponding orbit then an improved date of periastron may be calculated as 1977.7, giving a period of about 45.2 yr. If these values are adopted but the other orbital elements are left unchanged the residuals for both (c) Wierzbinski's elements and (d) Eggen's elements are considerably reduced.

\[ \text{HD 22262} \quad -31^\circ 1450 \]

The residuals are derived from elements by Finsen (1963). These are small despite the fact that the system was close to periastron (1977.8) when observed.

\[ \text{HD 26690} \quad \text{ADS 3064} \quad 46 \text{TAU} \]

Residuals are derived from elements by: (a) Finsen (1962) and (b) Starikova (1976). In both cases they are large. Observations by McAlister (1977a) in late 1975 and early 1976 also yielded large residuals. However, observations made by McAlister in late 1976 (1978, 1979) were in good agreement with both proposed orbits. Periastron occurred about 1976.2. Further observations are needed before any definite conclusions can be formed.

\[ -46^\circ 1347 \quad \text{RST 2338} \]

Residuals are derived from elements given by: (a) Van den Boss (1965) and (b) Newburg (1969).
HD 27176  51 TAU

This system is in the Hyades cluster. It has been discussed in some detail by Deutch, Lowen & Wallerstein (1971) who resolved it spectroscopically and by McAlister (1977b) who has resolved it interferometrically on several occasions (McAlister, 1977a, 1978, 1979).

These authors consider three possible situations:

(1) The distance of 51 Tau is that given by the convergent point of Wayman, Syms & Blackwell (1965) and the mass–luminosity relationship is that of Eggen (1967).

(2) The distance to 51 Tau is some 10 per cent greater than that given by Wayman et al. and the mass–luminosity relationship is normal.

(3) Deutch et al. suggest the possibility that the distance to the cluster is that given by the convergent point of Wayman et al. but that the mass–luminosity relationship is normal. In this case, by determining the mass of a Hyades visual binary system from the mass–luminosity relation and using this to calculate the semi-major axis, it is apparent that past measurement of the semi-major axes of Hyades visual binaries must contain systematic errors of about 20 per cent.

McAlister points out that only an extremely accurate measurement of the semi-major axis of the orbit would distinguish between the first two possibilities but suggests that the third possibility tends to be excluded.

Observations of four Hyades visual binaries ADS 3135, HD 27991, ADS 3248 and ADS 3475 are reported below. It is remarkable that the separation residuals are small and show no systematic trend. The mean modulus percentage separation residual for these binaries for all orbits (excluding case (b) for HD 27991) is 5.4 per cent and the percentage rms residual is 6.7 per cent. We feel that a systematic error as large as 20 per cent would be unambiguously detected by the speckle interferometric technique, and accordingly that the third possibility envisaged by Deutch et al. is untenable.

ADS 3135  55 TAU

ADS 3135, ADS 3248 and ADS 3475, all resolved in this paper, are visual binary systems in the Hyades cluster. Together with several other visual systems they are used by Alexander (1972) to demonstrate that the mass–luminosity relationship for the stars in the Hyades is poorly determined, and that, as yet, there is no firm evidence for a separate mass–luminosity relationship. ADS 3135 and ADS 3475 are also discussed in a paper by Wickes (1975) in which he endeavours to derive improved orbits by including a single interferometric observation of each system.

Residuals for ADS 3135 are quoted for the orbit by: (a) Wierzbinski (1958b) which is graded 2 by Finsen & Worley, for the orbit (b) derived by Wickes after including all the known observations and (c) the orbit derived by Wickes using only observations which Eggen (1963) defined as 'standard'. Wierzbinski's orbit yields a very small separation residual, whereas Wickes's orbit (b) gives the smaller position angle residual. Wickes concludes that observations so far do not indicate that a separate mass–luminosity relationship for the Hyades cluster is necessary. Assuming a mean cluster distance of 45.5 pc as calculated by Hanson (1975) Wierzbinski's elements place ADS 3135 very close to the normal mass–luminosity relationship. This would correspond to the case 2 proposed by Deutch et al. (1971). Using the same distance Heintz's elements for ADS 3475 also place the stars very close to the normal mass–luminosity relationship, and therefore, if Hanson's distance modulus is accepted, there appears to be no need to postulate a separate mass–luminosity relationship for these members of the Hyades cluster.
This observation resolves γ Tau (a member of the Hyades cluster) into two components. There are no previous records of this star being resolved as a binary, and further observations are needed.

**HD 27710  ADS 3159AB**

ADS 3159 consists of a triple system, of which the pair AB is resolved here; star C at 38 arcsec is a physical member of the system and there is a fourth optical component (D) at 45 arcsec. Residuals are derived from elements by Van den Bos (1951).

**HD 27820  ADS 3182  66 TAU**

This result and that given by McAlister (1979) yield large negative position angle residuals. Van Biesbroeck (1954) reports that his elements are very uncertain.

**HD 27991  70 TAU**

HD 27991 is a member of the Hyades group previously resolved by McAlister (1977a, 1978, 1979). Residuals are derived from three sets of elements, one: (a) by Couteau (1973) and two (b, c) by Finsen (1967, 1978). Finsen’s second set of elements are an improvement over the earlier orbit, although the position angle residual is still large. More observations may produce a further improvement.

**HD 28312  ADS 3230**

To avoid obtaining an unusually long period Horeschi (1957) assumed that measurements before 1915 were in the second quadrant. This observation is compatible with the resulting elements.

**ADS 3248**

ADS 3248 is a member of the Hyades cluster. Residuals are derived from elements by Van den Bos (1956). It is one of the Hyades visual binaries discussed by Alexander (see note on ADS 3135).

**ADS 3475**

ADS 3475 is a binary system in the Hyades cluster and has been discussed by Wickes and Alexander (see note on ADS 3135). This observation is in excellent agreement with the orbit given by: (a) Heintz (1969), which is graded 1 by Finsen & Worley, but yields larger residuals for both of the orbits (b, c) proposed by Wickes (1975).

**HD 37711  ADS 4265  126 TAU**

Whilst they give large residuals for the orbit proposed by Baize (1961), the separation and position angle observed here are both close to those reported by McAlister (1978, 1979), and the elements are therefore likely to be in error.
Observations of binary stars – III

HD 40932  ADS 4617  μ ORI

The system AB has been previously observed by Labeyrie et al. (1974), McAlister (1977a, 1978, 1979) and Morgan et al. (1978, 1980). Component B is resolved spectroscopically. Alden’s elements (1942) yielded large separation residuals for all these observations. It was noted by Morgan et al. that by modifying Alden’s elements so that \( P = 20.2 \) yr and \( T = 1929.8 \) the separation residuals could be considerably reduced, although the position angle residuals increased. The separation residual derived from the observation reported here demonstrates that Alden’s elements (a) require modification. The separation residual derived from the modified elements (b) is small for this, and for all the previous interferometric observations.

HD 41116  Kui 23  I GEM

This is a triple system comprising the visual binary AB, resolved here, and a spectroscopically resolved companion to B, for which a set of orbital elements have been published by Abt & Kallarakal (1963). Previous speckle observations have been made by McAlister (1978, 1979) and Morgan et al. (1980). Residuals are derived from elements by: (a) Heintz (1962), (b) Eggen (1965b) and (c) Abt. Both this and previous observations have favoured Heintz’s elements, although these still produce large position angle residuals. It was demonstrated by Morgan et al. that the residuals could be considerably reduced by retaining Heintz’s elements, but altering either the period to 13.48 yr (d) or the date of periastron to 1956.1 (e). This observation confirms that (d) and (e) are improvements on earlier elements, but does not indicate which is to be preferred.

HD 218060  ADS 16497  83 AQR

This object has been resolved by McAlister (1978). Elements have been derived by Hirst (1944). Finsen & Worley (1970) note that there is a radial velocity variation which may be due to the motion of the visual pair.

Conclusions

Twenty-five observations of 21 objects are presented. γ Tau is resolved into two components for the first time. Four of the objects resolved are visual binaries in the Hyades cluster, and the speckle interferometric technique is sufficiently accurate to demonstrate that there is no large systematic error in the semi-major axes quoted by the visual observers for these systems. Assuming Hanson’s (1975) distance modulus these observations place the stars on the normal mass–luminosity relationship and a separate relationship for the Hyades cluster is not then necessary.

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References


