

ICCD SPECKLE OBSERVATIONS OF BINARY STARS. VII. A DUPLICITY SURVEY OF THE HYADES CLUSTER

BRIAN D. MASON,¹ HAROLD A. MCALISTER,¹ WILLIAM I. HARTKOPF,¹ AND WILLIAM G. BAGNUOLO, JR.¹

Center for High Angular Resolution Astronomy, Georgia State University, Atlanta, Georgia 30303

Received 4 August 1992; revised 9 September 1992

ABSTRACT

The Hyades cluster is the nearest open cluster to the solar system, and its distance has long been a contentious issue. Recent work by Dombrowski (Ph.D. thesis, Georgia State University, 1991) included a calculation of the Hyades distance modulus based on binary star orbits. In order to expand the sample of Hyades binaries with potentially short-period visual orbits, a speckle survey of 153 bright Hyades stars ($V < 10$) for possible multiplicity was conducted at the KPNO 4 m Mayall telescope on 23–27 November 1991. Of these, one is graded as a suspected new binary, three are graded as possible new binaries, and three are graded as definite new binaries, one of which has been confirmed from examination of an archival observation from 1989. Of these seven new visual resolutions, six have possible spectroscopic components, two of which are probably the objects observed here, three certainly are not, and one may or may not be the component observed. Continued study of these candidate stars could further refine the Hyades distance modulus as well as the cluster mass–luminosity relation.

1. INTRODUCTION

Owing to its proximity to the Sun, the Hyades serves the critical role of luminosity calibration of all cluster main sequences, and hence is one of the lower-rungs in the cosmic distance ladder. The cluster distance has been determined through the convergent point analysis of proper motions and radial velocities, through direct observation of trigonometric parallaxes, and through studies of orbital motions of binaries. All three approaches depend upon reliable membership determinations, and the last two methods must deal with the nontrivial dispersion in distances to the member stars. We attempt here to use the enhanced capabilities of speckle interferometry, in comparison with classical techniques, to add to the list of binary and multiple stars in the Hyades. New systems will not only eventually help to improve our knowledge of the cluster distance, a quantity which continues to frustrate owing to the sometimes discrepant results from the three basic approaches, but they will also help to further our understanding of the formation and evolution of binary and multiple stars in the cluster environment and to calibrate the mass–luminosity relation for a star cluster of homogeneous composition.

2. SEARCH FOR HYADES MEMBERSHIP

The starting point for modern work on the Hyades is the survey and convergent point analysis of van Bueren (1952) who listed 152 bright Hyades members ($V < 9.0$)

on the basis of proper motion. Of these, 132 stars were listed as certain members with the addition of radial velocity data. Two stars (vB 98 and vB 125) were later rejected by Wayman *et al.* (1965), who also added 11 more members brighter than $V \approx +10$ on the basis of proper motions and radial velocities. Van Altena (1969) provided three more bright Hyades stars with a high probability of membership. More recently, Schwan (1991) again investigated Hyades membership using proper motion criteria and rejected four more van Bueren stars (3, 61, 80, and 110) along with one of the stars selected by Wayman *et al.* (1965), HD 25202. Schwan (1991) also added 13 more Hyades members. Considering stars brighter than $V = 10$ and rejecting any nonmembers from the above lists, we generated a final total of 153 Hyades stars to comprise our duplicity survey sample. Despite these selection criteria, it is likely that one or more actual Hyades members has been rejected and that one or more has been included which should have been rejected as a member.

3. OBSERVATION AND REDUCTION METHODOLOGY

The binary star speckle program at Georgia State University is a continuation of an effort begun at Kitt Peak National Observatory in 1975 by one of the authors (H. A. M.) of this paper. The Hyades survey observations were taken during our speckle observing run at the KPNO 4 m Mayall telescope on 23–27 November 1991. These data were collected with a new ITT camera with a single-stage intensified CCD, allowing reliable detection to a magnitude limit of $V \approx +10$ for 90 second integrations. The data were recorded on a Sony 8 mm videocassette recorder and then reduced with the “directed vector autocorrelation” (DVA) method described by Bagnuolo *et al.* (1992) and used in the sixth paper in this series (Hartkopf *et al.*

¹Visiting Astronomer, Kitt Peak National Observatory, National Optical Astronomy Observatories, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

TABLE 1. New binaries.

WDS	Name	HD	Grade	Epoch 1990.0+	V	Sp.	θ	ρ	P (yr)	K (km/s)	Notes
03327+3540	+35 714	21847	S	1991.8989	7.30	F8	358°77	0"222	25	6.5	(1)
04230+1732	vB 41	27697	P	1991.8995	3.76	K0III	354.9	0.273	23	8.5	(2)
04242+1446	vB 50	27836	P	1991.8992	7.62	G1V	8.3	0.262	33	5.5	(3)
04268+1052	J 271	286820	P	1991.8990	9.46	K5	77.6	0.175	24	5.0	(4)
04328+1600	vB 91	28783	D	1991.9021	8.87	K0	166.5	0.192	25	5.5	(5)
04375+1509	vB 102	29310	D	1991.9021	7.54	G0	232.6	0.235	29	6.0	(6)
				1989.2292			217.0	0.240			
04404+1631	vB 185	29608	D	1991.9021	9.48	K0	30.8	0.659	167	2.9	(7)

Notes to Table 1.

- (1) This object is a new addition to older Hyades member lists added by Schwan (1991), although Griffin (1992) doubts that this object is actually a cluster member.
- (2) This is a particularly unexpected result, given the four previous epochs at which our observations have shown no indications of duplicity. All four of the earlier observations were reanalyzed using the same procedures employed here, but no additional supporting evidence of duplicity was found. If this additional component is confirmed, vB 41 will be the second K0 giant binary that has been resolved in the Hyades (HR 1411 being the other). The common proper motion companion at a separation of 195" is far outside our window of observation, and the 530-day spectroscopic component of Griffin & Gunn (1977) would have an angular separation below the diffraction limit of the KPNO 4-m telescope.
- (3) Noted as a possible spectroscopic binary by Griffin *et al.* (1988) (here and after, G2), it is uncertain whether the system we detect here is also producing the radial velocity variation.
- (4) This K dwarf is noted as a binary with a period in excess of 16 years in G2, and it is likely that we have detected the spectroscopic companion.
- (5) CHARA 152 is probably the spectroscopic system found by G2 to have a period in excess of 15 years. The DVA of this observation is shown in Figure 2.
- (6) Reprocessing of archival speckle data have confirmed this already strong detection and have shown a change in θ of 15" in 2.7 yr. CHARA 153 cannot be the 2-yr spectroscopic system of G2. See Figure 3.
- (7) The spectroscopic orbit for HD 29608 (Griffin *et al.* 1985) (here and after, G1) is that of a much closer system, not the companion observed here and designated CHARA 154. See Figure 4.

1992). The sample was collected and reduced without prior knowledge of duplicity as a check on the reliability and completeness of detection.

Tables 1 and 2 contain measurements of seven new and nine previously known binary stars. The measured angular separations range from 0".175 to 0".659 for the new stars, and from 0".048 to 0".452 for the known binaries. The position angles for the new stars are consistent with the strongest quadrant given in the DVA; while some are convincing, none of them produces a definitive quadrant and there may still be a 180° ambiguity in position angle.

Table 3 contains 137 stars which exhibited no evidence of duplicity in this survey. The effective field of view of the CCD chip is about $1'.33 \times 1'.08$ centered on the primary star. Thus, the upper limit to angular separation was about 1", the lower limit being 0".035, the diffraction limit of the 4 m Mayall reflector. The stars with negative results may belong to one or more of three cases: (1) $\rho < 0".035$ or

TABLE 2. Known binaries.

WDS	Name	HD	Discoverer	Epoch	V	Sp.	θ	ρ	Notes
04185+2135	vB 24	27176	McA 14	1991.8938	5.56	A5	257°6	0".096	(1)
04256+1557	vB 57	27991	Fin 342	1991.8967	6.46	F7V	299.9	0.099	(2) †
04286+1557	vB 71	28307	McA 15	1991.8967	5.80	K0III	150.9	0.048	(3) †
04290+1610	vB 75	28363	Hu 1080	1991.8967	6.58	F8	257.1	0.411	(4) †
04340+1510	vB 96	285931	CHARA 17	1991.9021	8.70	K1	280.1	0.192	(5)
04506+1505	vB 120	30712	CHARA 20	1991.9023	8.10	G5	71.1	0.082	(6)
04512+1104	vB 122	30810	Bu 883	1991.8969	6.96	F5	353.1	0.209	(7) †
04518+1339	vB 124	30869	Bu 552	1991.8969	6.70	F8	185.4	0.452	(8) †
05098+2802	vB 132	33204	Bu 1047	1991.9023	8.10	G7	251.0	0.290	(9)

Notes to Table 2.

† Observation obtained when seeing FWHM $\geq 2"$.

- (1) HR 1331 (51 Tauri) is a spectroscopic binary first resolved with speckle interferometry by McAlister (1977). A new orbit with a period of 11.3 years was determined by Dombrowski (1991).
- (2) HR 1391 (70 Tauri) is another resolved spectroscopic binary (with $P = 6.28$ yr) discussed by McAlister *et al.* (1988) and by Dombrowski (1991).
- (3) HR 1411 (θ^1 Tau) is a long period interferometric companion in addition to the spectroscopic component suggested by Griffin & Gunn (1977) to have a period of about 16 years. An estimate of $\Delta m = 0.76$ was made by Dombrowski (1991). The wide bright companion HR 1412 (θ^2 Tau) is listed in Table 3.
- (4) A new orbit for ADS 3248 with $P = 40.15$ yr and $\Delta m = 0.65$ mag was determined by Dombrowski (1991).
- (5) This rapidly moving system within the wide binary ADS 3317 is probably the spectroscopic system with $P \approx 13$ yr found by G2.
- (6) This may be the spectroscopic system found by G2, but more observations are needed to determine the orbital motion.
- (7) A new orbit for ADS 3475 with $P = 16.30$ yr and $\Delta m = 0.19$ was determined by Dombrowski (1991). This star was noted as a spectroscopic binary by G2.
- (8) A new orbit for ADS 3483 with $P = 94.57$ yr was determined by Dombrowski (1991). The spectroscopic system with $P = 143$ days of G1 would be too close for us to resolve by speckle interferometry.
- (9) ADS 3730 is a visual binary with $P = 32.1$ yr and a large eccentricity ($e = 0.93$). Its elements are likely to be refined by speckle observations during its approach to periastron during the next 8 yr. The star was noted as a spectroscopic binary by G2.

$\rho > 1"$; (2) magnitude difference is greater than ~ 3.0 mag; or (3) they are single stars. The detection of close binaries can be effected by seeing conditions which were poor the first night of the run.

4. ARTIFICIAL BINARIES

We have started a program to evaluate the DVA and other algorithms producing quadrants and magnitude estimates. In the context of this paper, we can estimate some rough limits to binary star detectability and quadrant determination. A calcite crystal inserted into the optical path of our speckle camera in conjunction with a polarizing filter have been used to create artificial binary star speckle patterns (Bagnuolo *et al.* 1990; Barry *et al.* 1992). The birefringence of the calcite crystal produces two overlapping speckle patterns with a fixed offset and with orthogonal polarizations. The magnitude difference of the artificial binary can be varied by rotating the polarizing filter by an angle θ relative to the calcite crystal. If θ_0 is the angle at which the two components have equal intensity, then the intensity ratio varies as $\tan^2(\theta - \theta_0)$. The "stars" are perfectly isoplanatic, but all the other sources of noise (e.g., photon, detector, recording medium, and digitizer) are present. Thus, this method of physical simulation is much more realistic than simple computer simulations.

Three binary star simulations via the calcite crystal method were done on the November 1991 KPNO run. The stars used were ζ Per ($V = 2.85$ mag), 58 Per (4.25 mag) and HR 1712 (6.0 mag). The positions of the polarizer relative to the crystal were varied in 5° increments and 19, 20, and 20 data sets of 1 min each were taken, respectively, for the three stars. Seeing conditions were mediocre, roughly 1".2, and representative of much of the data taken on this run.

Figure 1 shows the intensities of the "left" and "right" peaks, respectively, for HR 1712 after our standard DVA algorithm has been applied with our usual background subtraction. The Δm 's have been estimated assuming the (Malus) $\tan^2$ law, with the crossover θ_0 angle determined to be 14° from the 58 Per and HR 1712 data.

The results of these simulations indicate that for very bright stars ($\sim$ third magnitude), the detection cutoff is about at 1% intensity or $\Delta m = 5$ magnitudes difference. The cutoff for quadrant discrimination may be conservatively estimated at 2%–3% ($\Delta m \approx 4$ mag). HR 1712 is a sixth magnitude star, more representative of most of our data. As can be seen in Fig. 1, the detection cutoff may be conservatively estimated at about $\Delta m = 3.5$ mag. The quadrant cutoff is at about $\Delta m = 3.0$ mag. The data also indicate that quadrants can be detected for components of nearly equal brightness having $\Delta m \gtrsim 0.2$ mag.

These results will be further extended by measurements with dimmer stars, but they indicate roughly the range of detectability and quadrant discrimination in our search for duplicity in the Hyades stars. We thus estimate that our detections of otherwise resolvable binaries have been limited to systems in which $\Delta m \lesssim 3.0$ mag for a sixth magnitude or brighter star, $\Delta m \lesssim 2.0$ mag for a seventh or eighth

TABLE 3. Negative results.

α, δ (2000)	Name	HD/DM	Notes	α, δ (2000)	Name	HD/DM	Notes
02578+2940	vB 153	+28 503		04276+1535	vB 65	28205	
02584+2040	vB 154	18404		04278+1144	vB 66	28237	
03174+0739	vB 1	20430	(1)	04280+2137	vB 67	28226	*
03175+0741	vB 2	20439		04281+1352	vB 178	28258	
03328+2342	vB 4	+23 465	†	04284+1352	vB 68	28294	*
03376+2121	vB 5	+20 598		04286+1911	vB 70	28305	
03532+1720	vB 6	24357	†	04286+1944	vB 69	28291	(31)
03551+1700	vB 7	285252		04287+1552	vB 72	28319	(32) *
03597+1020	vB 8	25102		04288+1303	vB 74	28355	*
04007+2023	vB 9	+19 641	(2) †	04288+1717	vB 73	28344	
04063+1542	vB 10	25825	†	04293+1733	vB 77	28394	(33) *
04077+1509	vB 11	26015	(3) † *	04295+1752	vB 78	28406	
04077+1509	vB 12	26015	(3) †	04295+1754	vB 79	285773	
04089+2912	MWC 2376	26090	(4) †	04295+2640	vB 76	283704	
04107+1825	vB 13	25345	† *	04300+1641	vB 180	28462	
04113+0532	vB 14	26462	(5) † *	04303+1950	vB 81	28483	(34)
04119+2338	CHARA 14	284163	(6) †	04306+1344	vB 84	28556	(35) *
04132+1646	VA 51	+16 570	†	04306+1542	vB 83	28546	(36) *
04144+1226	vB 18	26767		04306+1545	vB 182	28545	(37)
04144+1438	vB 17	26756		04306+1612	vB 82	28527	(38)
04145+2227	vB 16	26737	† *	04308+1609	vB 85	28568	
04145+2335	vB 15	26736		04309+1045	vB 86	28608	
04156+1042	vB 19	26784		04313+2008	vB 87	28593	
04157+2049	vB 162	26874	(7) † *	04315+1354	vB 88	+13 691	
04158+1524	vB 20	26911	† *	04316+1742	J 285	+17 744	(39)
04165+2154	vB 21	284235	†	04319+1551	vB 89	28677	
04176+1657	vB 22	27130	(8) †	04321+0525	vB 90	28736	
04180+1815	vB 23	27149	(9) † *	04330+1540	vB 92	28805	
04183+1605	vB 25	285690	†	04336+1646	vB 93	28878	
04187+1632	vB 29	27383	(10) †	04338+1315	vB 94	28911	
04190+1954	vB 26	27250	†	04338+1451	vB 95	28910	(40) *
04191+1732	vB 27	27282	†	04346+1530	vB 97	28992	
04198+1538	vB 28	27371	(11) † *	04346+1550	vB 183	28977	
04200+1402	vB 30	27397	† *	04361+1541	vB 99	29159	
04202+1914	vB 31	27406	†	04365+2320	vB 100	29169	
04204+1845	vB 32	27429	† *	04367+1155	LDS 1181	286900	(41)
04206+1506	vB 33	27459	† *	04367+1552	vB 101	29225	
04209+1352	vB 34	27483	(12)	04382+1230	vB 104	29388	(42)
04215+1825	vB 36	27534	*	04382+1603	vB 103	29375	(43) *
04215+2102	vB 35	27524	*	04389+1406	vB 106	29461	(44)
04216+1425	vB 37	27561	*	04389+2309	vB 105	29419	
04220+1405	vB 38	27628	(13)	04391+0752	vB 107	29499	
04224+1118	J 259	286770	(14)	04393+1555	vB 108	29488	
04228+1504	vB 40	27691	(15)	04401+2318	vB 109	284574	
04228+1647	vB 39	27685	(16)	04444+1109	vB 111	30034	(45)
04234+1647	vB 45	27749	(17)	04460+1142	vB 112	30210	
04234+1940	vB 43	284414	(18)	04465+1528	vB 142	30246	(46)
04234+2123	vB 42	27732		04468+0901	vB 113	30311	(47)
04235+1440	vB 46	27771		04468+1745	J 328	30264	(48)
04235+2424	vB 44	27731	*	04476+1816	vB 114	30355	(49)
04241+1727	vB 47	27819	(19) *	04487+2106	vB 115	284787	(50)
04242+1623	vB 48	27835		04491+1839	vB 116	30505	
04242+2144	vB 48	27808		04492+2448	vB 117	283882	(51)
04244+1705	vB 51	27848		04495+1553	vB 118	30589	
04245+1653	vB 52	27859	(20)	04504+1712	vB 119	30676	(52)
04247+0442	vB 140	27935	(21)	04508+1613	vB 121	30738	(53)
04249+1903	vB 53	27901	*	04514+1526	vB 143	30809	
04254+2212	vB 55	27946		04514+1850	vB 123	30780	
04254+2218	vB 54	27934	(22) *	04550+1929	vB 126	31236	
04255+1756	vB 56	27962	(23) *	04578+1400	vB 127	31609	
04256+1852	vB 58	27989	(24) †	04597+1555	vB 128	31845	(54)
04258+1802	vB 176	27990	(25)	05031+1343	vB 187	32347	
04259+1156	VA 379	+16 608		05031+2135	vB 129	32301	
04261+1531	vB 59	28034	(26)	05057+0628	vB 151	240629	(55) *
04263+1538	vB 141	28052	(27) *	05063+1740	SAO 94315	240648	
04263+2128	vB 62	28033	(28) *	05070+2809	—	240676	
04264+1651	vB 63	28068	(29)	05093+0950	vB 130	33254	(56)
04264+2249	vB 60	28024	(30) *	05098+2802	vB 131	33204	(57)
04267+1645	vB 64	28099					

Notes to TABLE 3

- † Observation obtained when seeing FWHM $\geq 2''$.
 * Earlier negative result in McAlister & Harikopf (1988) catalog.
- (1) ADS 2451 = Bu 1039 with $\rho = 2''.2$ and $\Delta m = 6.0$ is outside detection window.
 (2) SB with $P \geq 7$ yr according to G2.
 (3) ADS 2999 = STF 495 with $\rho = 3''.8$ is outside detection window.
 (4) ADS 3017 = Bu 1232 with predicted $\rho = ".038$ was apparently somewhat closer and thus unresolvable. G2 find this to be a SB but doubt its membership in the Hyades in spite of its inclusion by Wayman *et al.* (1965).
 (5) CPM companion with $\rho = 124''.1$ is outside detection window. An additional component was noted as spectroscopic by G2.
 (6) See discussion in Section 5. Griffin & Gunn (1981) found a 2.4-day SB.
 (7) The 55.1-day SB of Griffin & Gunn (1981) is outside detection window.
 (8) The 5.6-day SB of G1 is outside detection window.
 (9) The 75.6-day SB of Batten & Wallerstein (1973) is outside detection window.
 (10) ADS 3135 (see discussion in Section 5) is a SB according to G2.
 (11) HR 1346 = γ Tau. See discussion in Section 5.
 (12) The 3.06-day SB of Northcott & Wright (1952) is outside detection window.
 (13) The 2.14-day SB of Abt (1961) is outside detection window.
 (14) The 3-year SB of G2 is outside detection window.
 (15) The 255.5-year binary, ADS 3169 = STT 82 AB (see discussion in Section 5) is outside detection window. A wider companion (LDS 1166 AC, $\rho = 62''$, $M = 17.8$) and a 4-d SB of Sanford (1921) are also outside detection window.
 (16) SB with $P \geq 7$ yr according to G2.
 (17) The 8.418-day SB of Abt & Levy (1985) is outside detection window.
 (18) The 1.617-year SB of G1 is outside detection window.
 (19) CPM companion with $\rho = 143''.0$ is outside detection window.
 (20) Noted as a possible SB by G2.
 (21) The 156.4-day SB of G1 is outside detection window.
 (22) ADS 3201 = STF 9 is a multiple. STF 9 AB with $\rho = 339''.5$, STF 9 Aa with $\rho = 141''.1$ and STF 9 Bb with $\rho = 106''.9$ are all outside detection window.
 (23) Like the previous, ADS 3206 is a multiple. Kui 17 AB with $\rho = 1''.5$, and H 101 AB with $\rho = 77''.2$ are both outside detection window.
 (24) The 27.67-year binary, ADS 3210 (see discussion in Section 5) of Dornbrowski (1991) was observed at a time when atmospheric seeing was rated as poor. Also noted as a SB in G2.
 (25) SB with $P \geq 15$ yr according to G2.
 (26) SB with $P \geq 7$ yr according to G2.
 (27) CPM companion with $\rho = 134''.4$ is outside detection window. Also, noted as a 14.24-year SB by Abt (1965).
 (28) 8.55-day SB of Griffin & Gunn (1978) is outside detection window.
 (29) SB with $P \approx 7$ yr according to G1.
 (30) CPM companion with $\rho = 110''.2$ is outside detection window.
 (31) The 41.66-day SB of G1 is outside detection window.
 (32) The 140.7-day SB of Ebbighausen (1959) is outside detection window.
 (33) The 238.9-day SB of G1 is outside detection window.
 (34) Noted as a probable SB in G2.
 (35) CPM companion with $\rho = 111''.0$ is outside detection window with a large Δm of 5.8.
 (36) CPM companion with $\rho = 161''.8$ is outside detection window.
 (37) 358.4-day SB of Griffin & Gunn (1981) is outside detection window.
 (38) This was noted as a possible binary by Peterson *et al.* (1981).
 (39) 2.31-year SB according to G1.
 (40) 1.337-year SB according to Abt (1965).
 (41) ADS 3330 = LDS 1181 with $\rho = 29''$ is outside detection window. The secondary is also very faint ($M = 16.2$).
 (42) Two CPM companions with $\rho = 44''.1$ and $\rho = 119''.8$, both outside detection window.
 (43) CPM companion with $\rho = 140''.5$ is outside detection window.
 (44) SB with $P \approx 10$ yr according to G2.
 (45) Two CPM companions with $\rho = 74''.7$ and $\rho = 10''.0$, both outside detection window.
 (46) Noted as a SB in G2.
 (47) SB with $P \approx 7$ yr according to G2.
 (48) Noted as a slow SB in G2.
 (49) SB with $P \geq 5$ yr according to G2.
 (50) SB with $P \approx 4$ yr according to G2.
 (51) The 11.93-day SB of Griffin & Gunn (1978) is outside detection window.
 (52) Noted as a SB in G2.
 (53) The 5.751-day SB of Griffin & Gunn (1978) is outside detection window.
 (54) CPM companion with $\rho = 106''.4$ is outside detection window.
 (55) SB with $P \approx 2$ yr according to G2.
 (56) Two CPM companions with $\rho = 88''.6$ and $\rho = 168''.0$, both outside detection window.
 (57) STF 645 A, BC = ADS 3730 with $\rho = 11''.6$ is outside detection window. The BC component (Bu 1047) is resolvable and is measured in Table 2.

magnitude star, and $\Delta m \lesssim 1.0$ mag for a star of magnitude nine or fainter. These results will be further degraded by poor seeing as we discuss in the next section.

5. RESULTS

Seven previously unresolved binaries were found in this survey. This is somewhat surprising because none of these new systems has an angular separation making it inaccessible to visual observers. However, the typically low contrast of the DVA peaks for these objects implies Δm 's that might challenge micrometer observers.

The results for the new systems are summarized in Table 1. The first three columns contain various identifications: the first is the epoch-2000 coordinate given in the manner of the *WDS* designation (from the *Washington Double Star Catalog* maintained at the U.S. Naval Observatory by C. E. Worley), followed by the star name and the HD number. The fourth column is a one-letter code which indicates whether the new binary is "suspected" (S), "probable" (P), or "definite" (D). Suspected binaries are those which may exhibit duplicity, but the DVA peak of the secondary is not strong. Probable binaries are those which have secondary peaks which are convincing but would still require confirmation. Definite binaries are those whose peaks are significantly stronger and, while confirmation is desirable, it is not necessary to convince us of the reality of the detection. In the notes to Table 1, we assign "CHARA" discovery designations, continuing the sequence from previous papers (cf. Hartkopf *et al.* 1992). In one case, confirmation has been obtained from reanalysis of

an observation from an earlier epoch. The fifth column is the epoch of the observation expressed as fractional Besselian year. The sixth column contains the visual magnitude of the star, and the seventh column the spectral type. Columns eight and nine give the measured position angle (θ) and the angular separation (ρ). Columns ten and eleven give crude estimates of the orbital period (P) and velocity amplitude (K) of these stars, assuming (1) equal-mass components, (2) a circular orbit, (3) an inclination of 90° , and (4) centered in the Hyades with a distance modulus of 3.42 mag. All of these are slow-moving binaries, but their K values and wealth of spectral features (since they are mostly late-type stars) make them potential candidates for precise radial velocity programs. This could eventually lead to orbital parallaxes.

Figure 2 is a "cross-section" of the DVA for vB 91 passing (left to right) through the principal, central, and ghost peaks. The background has been removed by the boxcar method described in Bagnuolo *et al.* (1992) and the central peak has been truncated to bring up the other peaks. Figure 3 is a similarly treated cross-section of the DVA for vB 102 passing (left to right) through the ghost, central, and principal peaks. Many of the newly resolved binaries are in the lower-half of the main sequence, unlike most of the known visual or interferometric binaries listed in Table 2. Coverage of this lower portion of the main sequence could eventually lead to stellar masses and refinement of the mass-luminosity relation. Figure 4 is a cross-

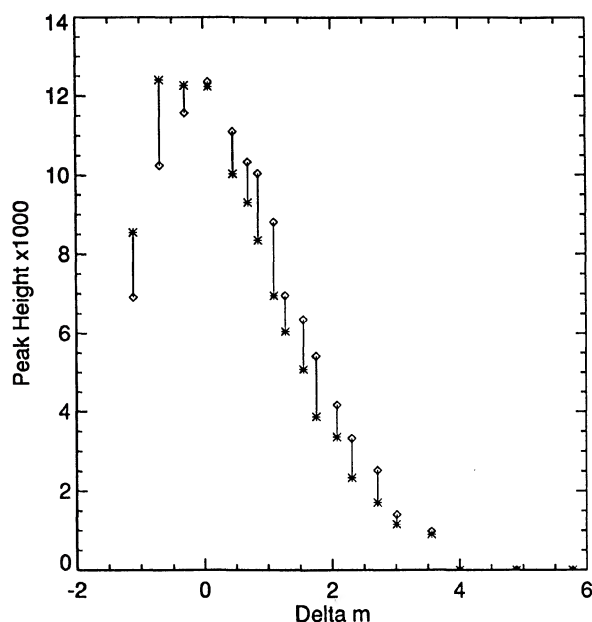


FIG. 1. A series of simulated binary stars from Calcite/polarizer method for a 6.0 mag star (HR 1712). Asterisk: left peak, Diamond, right peak. Simulated separation was approximately 5.94 and 12.26 pixels in x and y , respectively, corresponding to $0''.121$.

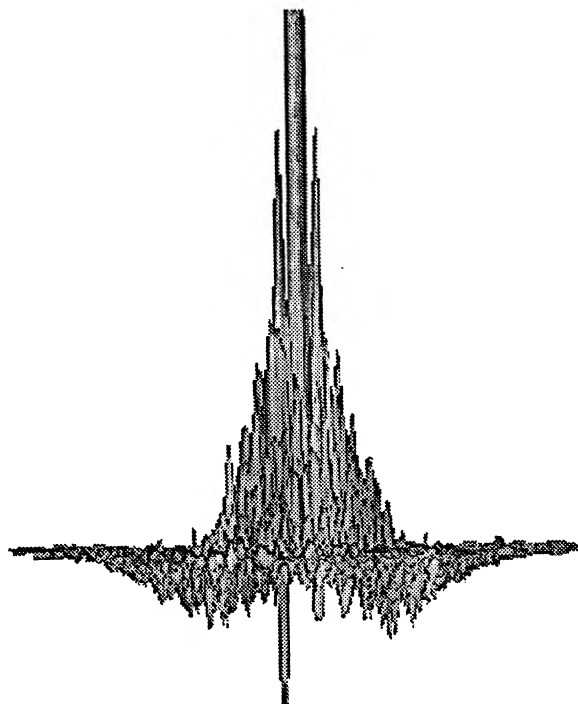


FIG. 2. The central region of the directed vector-autocorrelation of the binary system van Bueren 91 is shown. The truncated central peak corresponds to the zeroth order spatial correlations (i.e., speckles correlating with themselves) while the two side peaks arise from the system duplicity. This is shown following background subtraction.

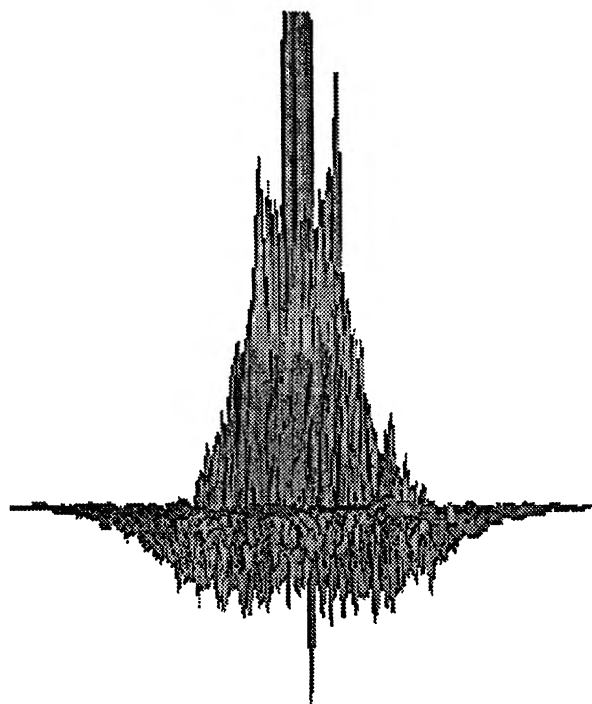


FIG. 3. The central region of the directed vector-autocorrelation of the binary system van Bueren 102 is shown. The true quadrant is more obvious than in the previous figure showing (from left to right) ghost, central, and principal peak. This is shown with the central peak truncated and following background subtraction.

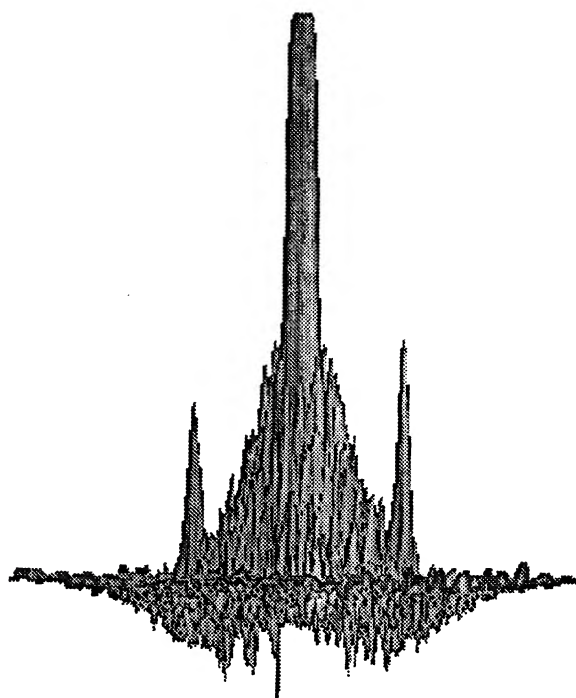


FIG. 4. The central region of the directed vector-autocorrelation of the binary system vB 185 is shown. This figure also shows a good quadrant showing (from left to right) ghost, central, and principal peak. This is shown with the central peak truncated and following background subtraction.

section of the DVA for vB 185 passing (left to right) through the ghost, central, and principal peaks.

Measurements for nine previously known visual or interferometric binaries (McAlister & Hartkopf 1988) are summarized in Table 2. The first four columns contain various identifications: *WDS* designation, star name, the HD number, and the discoverer designation. The fifth column is the epoch of the observation; the sixth column contains approximate visual magnitude of the star, and the seventh column the spectral type. The final two columns give the relative position of the secondary.

Table 3 summarizes the 137 negative results. Column one gives the 2000 coordinates of the star. The second column is the star name, and the third column is the HD or DM number. All of these observations were made between 1991.89 and 1991.90. Of the 137 stars listed in Table 3, 22 are listed in the *WDS*. Of those, 16 stars are listed in the *WDS* as having separations exceeding $2''$, so they fall well outside the field of view. ADS 3169=vB 40 has a separation of approximately $1''.4$, and while this is outside the north-south separation of our window, we see evidence in the DVA of a peak just outside the window at the expected position angle according to the orbit in the Worley & Heintz (1983) orbit catalog. However, it is not possible to measure a position for this object. Of the remaining five, vB 28 was observed to exhibit no duplicity in this survey. It has only one published measurement, the speckle result of Morgan *et al.* (1982) who reported a large magnitude dif-

ference. It was observed by us when the seeing was approximately $2''$, which might explain the lack of observed duplicity of this unconfirmed binary. MWC 2376=Bu 1232=ADS 3017 ($V=9.0$, $\Delta m=0.8$) has a grade 3 published orbit (Worley & Heintz 1983), which predicts a measurement of $279^\circ.2$ at $0^h03^m.8$. This is near the resolution limit of the Mayall telescope, and the star may actually come within this limit due to the uncertainty in the orbit. This is an object warranting further study in the very near future as it is very close to periastron passage. Poor atmospheric seeing is responsible for not resolving three other well-known binaries. CHARA 14 ($V=9.4$, no published Δm) has been observed interferometrically on five other occasions, three of which produced peaks under good seeing conditions. At the time this observation was made, the seeing was noted to be $2''.5$. It is suspected that the poor seeing is completely obscuring the duplicity for this binary. Observed at about the same time, under confirmed poor ($2''.5$) seeing was ADS 3135=vB 29 ($V=7.2$, $\Delta m=1.0$). Its most recent separation was $0''.285$. ADS 3210=vB 58 ($V=8.8$, $\Delta m=0.5$), whose most recent measured separation was $0''.252$, was observed the following night when the seeing was noted to be about $2''$ with some cirrus. We have indicated those stars in Tables 2 and 3 that were observed during times of poor seeing. We conclude that $\Delta m \gtrsim 0.5$ mag may preclude detection of duplicity under conditions such as were encountered here. A negative result for these stars is less convincing than for other stars. We note that

none of the new binaries in Table 1 were detected under inferior seeing conditions.

We conclude that, except for omissions resulting from transient poor seeing, we have not overlooked any previously known resolved binaries in our Hyades sample whose angular separation is within the "window" of detectability of our observing speckle program. We hope other observers will attempt to confirm the newly resolved systems in Table 1.

The first author (B.D.M.) appreciates the guidance of Don Barry during his first speckle experience at the KPNO 4 m telescope. We thank Roger Griffin for many helpful comments following his critical reading of a draft manuscript. We acknowledge the help and support of the LTO's

at Kitt Peak: Dave Chamberlin, Jennifer Hedden, Jean Nowakowski, Hal Halbedel, and Bill Binkert. We also would like to thank Steve Lane for assistance in getting our new detector on line and Hal Halbedel for calibration assistance. This research has made use of the SIMBAD database, compiled at CDS, Strasbourg, France. The binary star speckle program at Georgia State University has been supported by the National Science Foundation, most recently through NSF Grant No. AST 91-41927. Institutional support has been provided from the GSU College of Arts and Sciences and from the Chancellor's Initiative Fund from the Board of Regents of the University System of Georgia administered through the GSU office of the Vice President for Research and Technology. We gratefully acknowledge this support.

REFERENCES

- Abt, H. A. 1961, *ApJS*, 6, 37
 Abt, H. A. 1965, *ApJS*, 11, 429
 Abt, H. A., & Levy, S. G. 1985, *ApJS*, 59, 229
 Bagnuolo, W. G., Jr., Barry, D. J., Mason, B. D., & Dombrowski, E. G. 1990, *Proceedings of the SPIE on Amplitude and Spatial Interferometry*, edited by J. Breckinridge, Vol. 1237, p. 286
 Bagnuolo, W. G., Jr., Mason, B. D., Barry, D. J., Hartkopf, W. I., & McAlister, H. A. 1992, *AJ*, 103, 1399
 Barry, D. J., Bagnuolo, W. G., Jr., Mason, B. D., McAlister, H. A., & Turner, N. H. 1992, in *IAU Colloquium No. 135, Complementary Approaches to Double and Multiple Star Research*, ASP Conference Series, edited by H. A. McAlister and W. I. Hartkopf (ASP, San Francisco)
 Batten, A. H., & Wallerstein, G. 1973, *P Dom Ap O*, Victoria, B.C., 14, 135
 Ebbighausen, E. G. 1959, *P Dom Ap O*, Victoria, B.C., 11, 235
 Dombrowski, E. G. 1991, Ph.D. thesis, Georgia State University
 Griffin, R. F. 1992, private communication
 Griffin, R. F., & Gunn, J. E. 1977, *AJ*, 82, 176
 Griffin, R. F., & Gunn, J. E. 1978, *AJ*, 83, 1114
 Griffin, R. F., & Gunn, J. E. 1981, *AJ*, 86, 588
 Griffin, R. F., Gunn, J. E., Zimmerman, B. A., & Griffin, R. E. M. 1985, *AJ*, 90, 609
 Griffin, R. F., Gunn, J. E., Zimmerman, B. A., & Griffin, R. E. M. 1988, *AJ*, 96, 172
 Hartkopf, W. I., McAlister, H. A., & Franz, O. G. 1992, *AJ*, 104, 810
 McAlister, H. A. 1977, *ApJ*, 215, 159
 McAlister, H. A., & Hartkopf, W. I. 1988, *Second Catalog of Interferometric Measurements of Binary Stars*, CHARA Contribution No. 2, Georgia State University
 McAlister, H. A., Hartkopf, W. I., Bagnuolo, W. G., Jr., Sowell, J. R., Franz, O. G., & Evans, D. S. 1988, *AJ*, 96, 1431
 Morgan, B. L., Beckmann, G. K., Scadden, R. J., & Vine, H. A. 1982, *MNRAS*, 198, 817
 Northcott, R. J., & Wright, K. O. 1952, *JRASC*, 46, 11
 Peterson, D. M., Baron, R. L., Dunham, E., Mink, D., Weekes, T. C., & Elliot, J. L. 1981, *AJ*, 86, 280
 Sanford, R. F. 1921, *ApJ*, 53, 201
 Schwan, H. 1991, *A&A*, 243, 386
 Van Altena, W. F. 1969, *AJ*, 74, 2
 Van Bueren, H. G. 1952, *BAN*, 9, 385
 Wayman, P. A., Symms, L. S. T., & Blackwell, K. C. 1965, *Royal Obs. Bull.*, 98
 Worley, C. E., & Douglass, G. G. 1984, *Washington Double Star Catalog*, USNO, Washington, DC
 Worley, C. E., & Heintz, W. D. 1983, *Pub. U.S. Naval Obs.*, 24, Part VII