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An Adaptive Optics Search for Visual Binaries in M 34

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Abstract. We have used the PUEO adaptive optics camera on the Canada–France–Hawaii Telescope (CFHT) to carry out a search for visual binaries among the late-type members of the M 34 cluster. Of the 94 stars observed, 17 were resolved into close pairs. The observed separations range from 0.″09 to 6.″4, corresponding to 40–3000 AU (the latter being a safe upper limit for bound solar-type binaries). We carried out the survey at a single infrared wavelength, in the H band at 1.63 μm. Additional color information will be needed to eliminate field stars and to establish which of the observed doubles are bona fide physical pairs. If the observed binary candidates are true companions, the masses we infer for the secondaries range from 0.09 $M_{\odot}$ to 1.5 $M_{\odot}$, and the mass ratios, q, range from 0.1 to 1.

1. Introduction

M 34 (= NGC 1039) is a 220 Myr old open cluster, which lies within the broad age gap between the Pleiades and Hyades clusters (Meynet et al. 1993). Among other properties, the X-ray luminosities, rotational velocities, and light element abundances of the solar-type stars in M 34 appear to be intermediate between those of the Pleiades and Hyades (Jones et al. 1997; Simon 2000), consistent with the relative ages of the three clusters. The distance to M 34 is ∼475 pc, and the reddening out to that distance is found to be very slight, $E(B-V) = 0.07$. Cluster membership is known independently from two modern proper motion studies, the first by Ianna & Schlemmer (1993), the other by Jones & Prosser (1996).

2. The Search for Cluster Binaries

M 34 was observed as a secondary target in the course of our study of the binary properties of young star forming regions and older clusters (e.g., IC 348: Duchêne et al. 1999; Praesepe: Bouvier et al. 2001). Our goal in this program is to learn how the formation as well as the survival of binary stars in these regions is affected by environmental conditions and by evolutionary processes. For this

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study we have been using the PUEO adaptive optics camera on the Canada–France–Hawaii Telescope (Rigaut et al. 1998). With PUEO we routinely resolve visual binaries with projected separations as small as $0\farcs06$, as long as the infrared magnitudes of the primary and secondary stars are not too dissimilar, i.e., $\Delta H \leq 1.5$ mags. At $1''$ separation, companions up to $6\frac{1}{2}$ magnitudes fainter than their primaries can be seen with ease.

We chose M 34 as a backup target mainly because of its location on the sky, but also in anticipation that a catalog of binaries in this cluster would prove useful to future X-ray imaging work with Chandra or XMM-Newton. To save time while surveying the largest number of late-type stars in the cluster, we used a "quick survey" mode, imaging each star at a single location on the camera rather than at our customary four dithered pointings, and we also observed in just the H band instead of in all three JHK infrared bands that we would normally use. The limitation of this approach is that we have no color or spectral information that would help to determine whether the new companions we have found are members of physical pairs within the cluster or are merely field stars accidentally projected along the line of sight. The true status of these candidate binaries therefore remains to be determined.

3. Results

Ninety-four high probability, low-mass members of M 34 were observed. The images of individual stars were sky-subtracted, flat-fielded, measured with aperture photometry and PSF fitting routines in IRAF, and calibrated against infrared photometric standards in the usual way. We resolved 15 stars into close doubles, 2 others into triple systems. The narrowest pair resolved is JP 137, which has an angular separation of $0\farcs09$, or 40 AU at the distance of M 34. The relative photometry and astrometry of this system (and of the other tight pairs) were determined both by PSF fitting and by image deconvolution. A combined surface and contour plot for this star is shown in Figure 1, along with a similar plot for the more typical pair represented by JP 570. To restrict the number of chance projections of field stars, we imposed a radial cut-off at $6\farcs4$, or 3000 AU, which is a safe upper limit for the orbit of a bound solar-type binary.

Table 1 summarizes our measurements for the resolved stars. Table 2 lists the stars that were not resolved. The $(V, B-V)$ photometry and membership probabilities (Pr) cited in Table 1 are those supplied by Jones & Prosser (JP) or Ianna & Schlemmer (UV). Our infrared magnitude for the primary star, H_A, the relative magnitude of the secondary, ΔH_{AB}, the angular separation, and the position angle follow in succeeding columns. The P.A. is measured in the usual sense, from north through east. JP 113, 227, 319, and 435 are the only stars in this list to show obvious signs of a companion on the Digital Sky Survey.

The last three columns of Table 1 list the masses of the individual primary and secondary components and the resulting mass ratio. The mass estimates were derived from an infrared M_H absolute magnitude–mass relation, which we extracted from the evolutionary models of Siess et al. (2000), given the age and distance of M 34 cited above. The masses we infer for the secondaries range from $0.09\,M_\odot$ to $1.5\,M_\odot$, the corresponding mass ratios are $0.1 \leq q \leq 1$.

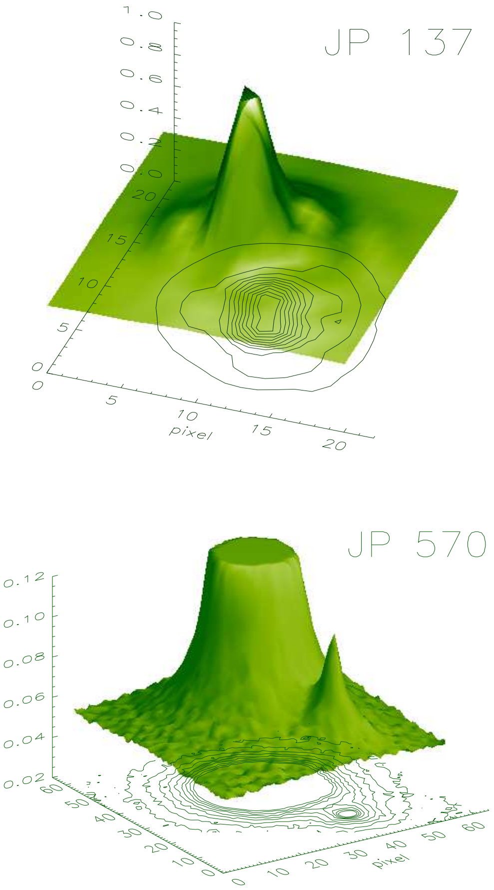

Figure 1. Surface plot and contour plot for the H band images of JP 137 (*top*) and JP 570 (*bottom*).

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Table 1. Visual Binary Stars in M 34

Name	V	$B-V$	Pr	H_A	ΔH_{AB}	$\rho\,('')$	P.A. (°)	M_A	M_B	q
JP 113[a]	14.86	0.88	84	13.08	3.54	3.49	142.3	0.73	0.16	0.22
″	14.86	0.88	84	13.08	4.76	2.61	6.9	0.73	0.09	0.13
JP 137	10.62	0.33	99	10.77	0.04	0.09	196.7	1.50	1.48	0.99
JP 165	12.83	0.62	99	11.13	4.56	1.02	55.0	1.34	0.29	0.21
JP 224	14.40	0.84	91	12.51	4.20	1.25	321.8	0.87	0.15	0.18
JP 227	14.44	0.83	92	12.53	1.38	5.20	74.8	0.86	0.56	0.65
JP 303	13.67	0.85	95	12.14	0.14	0.33	61.8	0.98	0.94	0.96
JP 319[a]	13.11	0.79	98	11.36	2.13	4.26	131.0	1.23	0.64	0.52
″	13.11	0.79	98	11.36	3.02	5.38	150.7	1.23	0.48	0.39
JP 320	13.48	0.80	98	11.51	2.25	0.77	261.4	1.18	0.59	0.50
JP 366	13.72	0.73	94	12.06	4.00	3.10	246.0	1.00	0.24	0.24
JP 374	11.64	0.44	99	10.55	2.07	0.21	113.9	1.61	0.84	0.52
JP 392	15.49	1.01	62	12.90	2.87	2.45	259.5	0.77	0.27	0.36
JP 435[b]	11.45	0.34	97	10.64	3.28	6.40	311.0	1.57	0.56	0.36
JP 451	12.33	0.50	98	11.03	2.53	0.30	281.3	1.37	0.63	0.46
JP 489	15.00	0.95	67	12.67	5.21	1.84	129.0	0.83	0.09	0.11
JP 570	14.74	0.95	72	12.46	3.03[c]	0.80	197.5	0.89	0.31	0.35
UV 52	12.86	0.91	79	11.27	5.88	1.50	271.0	1.26	0.13	0.10
UV 62	11.40	0.63	88	10.40	5.96	1.37	17.4	1.72	0.18	0.11

[a] Triple system. Entries on separate lines are for AB and AC.
[b] Secondary itself may be double.
[c] Uncertain flux difference, ±0.13 mag.

Table 2. Stars that are Unresolved in Our Survey

JP numbers of single stars									
17	42	51	59	63	118	124	133	146	150
155	156	158	177	179	190	199	206	208	213
216	219	246	257	266	270	275	280	282	288
289	290	296	297	298	305	315	317	329	331
335	338	362	375	377	397	404	415	424	425
433	434	454	465	482	483	484	488	502	503
504	515	532	546	548	556	568	594	603	604
625									
UV numbers of single stars									
4	7	48	61	309	310	323			