Astron. Astrophys. 323, 139–150 (1997)

ASTRONOMY AND ASTROPHYSICS

Pleiades low-mass binaries: do companions affect the evolution of protoplanetary disks?*,**

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Received 3 December 1996 / Accepted 3 January 1997

Abstract. We have observed 144 G and K dwarf members of the Pleiades cluster to search for close multiple systems using CFHT's Adaptive Optics adaptor in the near-IR. We detected 22 binary systems and 3 triples, with a separation between 0.08 and 6.9 arcsec (11–910 AU). After correction for incompleteness, we derive a binary frequency in the orbital period range from 4.2 to 7.1 log days, of 28 $\pm$ 4% for G and K Pleiades dwarfs, similar to that of field G-type dwarfs (27%). The distributions of both orbital periods and mass-ratios of the Pleiades systems also appear similar to those of G dwarf binaries of the field. The binary frequency in the 100 Myr-old Pleiades cluster is much lower than that observed for Myr-old pre-main sequence (PMS) stars in the Taurus-Auriga cloud. We argue that this difference does *not* result from the evolution of the binary systems during the pre-main sequence. Instead, we suggest that the low Pleiades binary frequency is typical of stellar populations formed in dense protoclusters, while the higher binary frequency observed among Tau-Aur PMS stars is more typical of loose T associations. The implication is that most field stars are born in dense protostellar clusters.

All 144 surveyed stars have known rotational velocities. Based on the current beliefs that i) the rotation rate of Pleiades late-type dwarfs is largely dictated by the lifetime of their pre-main sequence circumstellar disks and that ii) the evolution of the disks is affected by the presence of a close companion, we searched for a relationship between rotational velocity and binarity among Pleiades G and K dwarfs. We find no significant difference between the distribution of rotational velocities of single and binary stars. Unless current models of PMS angular momentum evolution are flawed, this indicates that the presence of a companion within a distance of 10-1000 AU does not prevent accretion from occurring onto the primary at a rate similar to that observed for single PMS stars. For the closest systems, this implies that accretion must proceed from the *circumbinary* disk onto the central stars. For slightly wider systems, it suggests that the truncated circumstellar disks of the primary and of the secondary are fed by an external (circumbinary) reservoir of mass.

Key words: stars: binaries: close – stars: formation – stars: pre-main sequence – stars: rotation – Galaxy: open clusters and associations: Pleiades (Melotte 22) – circumstellar matter

1. Introduction

In the solar neighborhood, binary systems are known to outnumber single stars. Spectroscopic and high-angular resolution surveys aimed at characterizing the binary populations of stellar groups of various ages and belonging to different environments will help to understand why the preferred output of the stellar formation process are binary systems, how the properties of these systems change with time, and how local conditions in star forming regions affect their formation and survival. Recent surveys have mainly focused on late-type field dwarfs (Duquennoy & Mayor 1991, Fisher & Marcy 1992, Tokovinine 1992) and young low-mass pre-main sequence (PMS) stars (Ghez et al. 1993, Leinert et al. 1993, Reipurth & Zinnecker 1993, Prosser et al. 1994, Simon et al. 1995, Brandner et al. 1996). Except for the long-term spectroscopic survey of Pleiades low-mass dwarfs carried out by Mermilliod et al. (1992), and the extensive photometric surveys of Stauffer (1984) and van Leeuwen et al. (1986), much less is known on the population of low-mass binaries in young open clusters. Yet, clusters such as Pleiades or Alpha Persei are located approximately midway in age (50-100

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* Based on observations obtained at the Canada-France-Hawaii Telescope.

** Table 3 is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

Myr) between the young PMS stars (a few Myr) and the much older field stars (a few Gyr). Therefore, investigation of their binary population may bring clues to the evolution of binary systems from the PMS to the MS. Besides, the extensive photometric and spectroscopic studies of the low-mass population of young open clusters have already led to a complete renewal of the concepts related to both angular momentum evolution of young solar-type stars (Stauffer 1991) and the physics of depletion of light chemical elements in stellar interiors (Balachandran 1994). Whether binarity adds a degree of complexity in the understanding of these processes has not been fully elucidated yet (Stauffer & Hartmann 1987).

The search for low-mass multiple systems in the Pleiades was motivated by the following specific issues:

1) The binary frequency among low-mass PMS stars (age: 1-10 Myr) appears to be very high: between 80 and 100% in Taurus and Ophichius T Tauri associations (Ghez et al. 1993, Leinert et al. 1993, Reipurth & Zinnecker 1993, Simon et al. 1995) while among late-type field dwarfs (age$\geq$1 Gyr), the binary frequency amounts to about 60% (Duquennoy & Mayor 1991, Fisher & Marcy 1992, Tokovinine 1992). This difference may either be due to an evolution of the binary frequency with time, as multiple systems are disrupted (Ghez et al. 1993) or may indicate different modes of star formation between T Tauri associations and field stars (Prosser et al. 1994). Deriving the binary frequency among low-mass Pleiades members, with an age of 100$\pm$20 Myr, i.e., intermediate between PMS and field stars, will help to decide between these two interpretations.

2) Low-mass Pleiades members exhibit a wide range of rotational velocities from 5 to 200 km s^{-1} (Stauffer & Hartmann 1987, Soderblom et al. 1993, Allain et al. 1996). This wide distribution of velocities is believed to result from the PMS evolution of protoplanetary disks. Because interaction with the disk acts to brake the central star (Königl 1991, Bouvier et al. 1993, Edwards et al. 1993), stars with long-lived disks will reach the zero-age main sequence (ZAMS) as slow rotators, those with short-lived disks as fast rotators. In turn, the evolution of circumstellar disks during the pre-main sequence is thought to be influenced by the presence of a companion: in binary systems, the disk may be expected to be rapidly disrupted by tidal effects from the companion. Because the rotational velocity of Pleiades low-mass dwarfs is largely dictated by the PMS disk lifetime and, in turn, the disk lifetime is thought to be affected by the presence of a companion, one would predict to observe some relationship between rotation and binarity on the ZAMS. If the companions act to quickly disrupt the disk (Pringle 1991, Artimowicz 1992), the fraction of binaries ought to be higher among Pleiades fast rotators than among slow rotators. Yet, Stauffer & Hartmann (1987) found that fast rotators were less often displaced above the Pleiades ZAMS than slow ones, suggesting that more of the latter were photometric binaries. In order to address this issue, we observed all G and K stars of the central part of the Pleiades cluster with known rotational velocities.

3) Because the Pleiades cluster harbors a young, coeval and relatively nearby (130 pc) stellar population, it is well suited to investigate the lower-ZAMS mass function (Meusinger et al. 1996). A survey of close binary systems provides a new estimate of how much mass resides in low-mass companions. Moreover, at the distance and age of the Pleiades, very low-mass companions at the hydrogen-burning mass limit (0.08 $M_\odot$) have a K-magnitude of about 14 (Basri et al. 1996, Tsuji et al. 1996), which lies well within the detection capabilities of the present survey.

4) on the longer term, high angular resolution monitoring of Pleiades binary systems with an orbital period of a few 10 yrs (corresponding to a separation of 0.1$''$, within the grasp of adaptive optics techniques) will provide visual orbits which, completed by radial velocity monitoring, will yield direct estimates of the stellar masses. Such dynamical mass determinations are important for establishing the mass-luminosity relationship on the lower main sequence as well as to test pre-main sequence evolutionary tracks for low-mass stars, since the very low-mass Pleiades members are still in their PMS contraction phase.

In Sect. 2, we describe the observations performed with CFHT's adaptive optics system and the data reduction procedure. In Sect. 3, we present the results on Pleiades binary frequency, the properties of the companions, and the connection between binarity and rotation. In Sect. 4, we discuss the implication of these results for the formation and evolution of binary systems and for the physics of the accretion process in young binaries.

2. Observations and data reduction

Because our study was primarily motivated by the search for a relationship between binarity and stellar rotation, we observed G and K-type members of the Pleiades ($0.56 \leq (B-V)_o \leq 1.5$) with known rotational velocity (Stauffer et al. 1984, Stauffer & Hartmann 1987, Soderblom et al. 1993, Allain et al. 1996, Queloz et al. 1996). The sample consists of 144 stars and includes most of all known G and K dwarfs located in the central part of the Pleiades cluster but none of the dwarfs located in the outer regions of the cluster (see Soderblom et al. 1993 and references therein). Stars with spectral type between G0 to K7 are evenly represented in this sample as illustrated in Fig. 1.

All the sources were observed at the 3.6-m Canada–France–Hawaii telescope (CFHT) during 6 half-nights from September 25 to October 1, 1996, using Université de Montréal Infrared Camera Monica (Nadeau et al. 1994) and CFHT's adaptive optics adaptor PUEO. Monica includes a Nicmos 3 256^2 pixel array, with a plate scale of 0.0344 arcsec/pixel, yielding a field-of-view of 9$''$. PUEO provides diffraction-limited images in the H and K-band when using a star up to a R magnitude of 14 for wavefront correction (McArthur et al. 1996). All of the images obtained during this survey are diffraction-limited in the H and K band, and partially corrected in the J-band.

Every target was first observed in the K-band and whenever it appeared to be multiple it was further observed in the H and J bands. The total exposure time in each filter usually was 2.5 minutes and consists of 5 30s-exposures shifted on the IR array in order to allow proper sky subtraction. The common sky area covered by all 5 individual exposures is about 3$''$. The individual

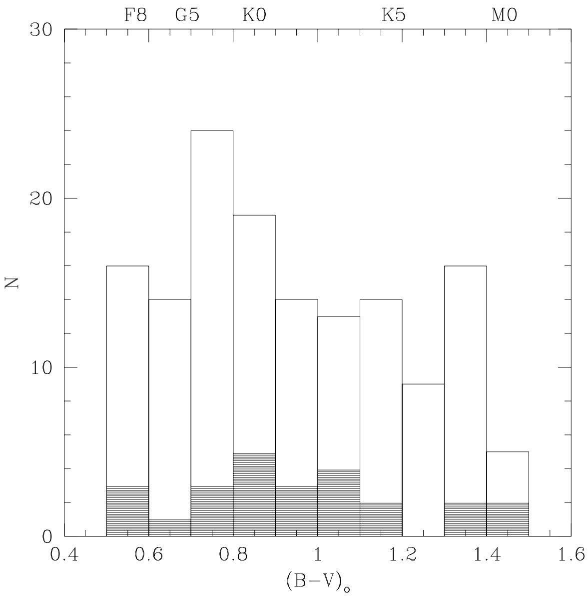

Fig. 1. The stellar sample: the upper histogram of $(B - V)_o$ is for the whole sample, and the lower hatched one for the detected multiple systems only.

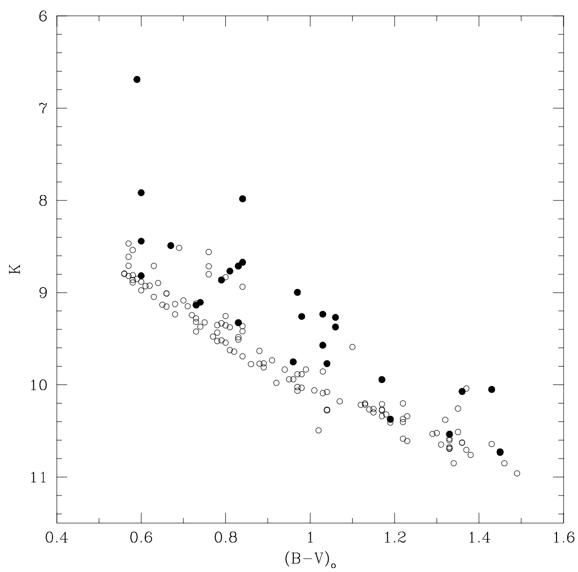

Fig. 2. Color-magnitude diagram of the binaries detected in the survey (filled dots) and unresolved Pleiades G and K dwarfs (empty dots).

30s exposures were sky subtracted, flat fielded, corrected from bad pixels, and shift-and-added to yield the final images. No deconvolution process was applied to the images.

The PSF fitting method available in the NOAO IRAF/DAOPHOT package was used to derive the astrometric properties of the binary systems as well as differential photometry between the primary and the secondary. The differential photometry was then combined with aperture photometry over the whole system in order to derive the JHK magnitudes of the components of the systems. UKIRT Faint Photometric Standards were observed during the run and used for photometric calibration. From the analysis of the images, we estimate the completeness limit up to K=17 at a separation greater than 1″ (see 3.1), i.e., an absolute K magnitude of 11.4, well within the substellar mass domain (Henry & McCarthy 1993).

The average rms error is 0.01 mag for differential photometry, 0.05 mag for absolute photometry, 0.005″ on the projected separation, and 0.15 deg on the position angle. The error is slightly larger for systems with a separation close to the diffraction limit of the telescope and for the photometry of the faintest companions.

3. Results

We have detected 30 close pairs among the 144 Pleiades G and K dwarfs of the sample. The results are listed in Table 1. HII 2500, HII 3197 and MT61 are triple systems and therefore appear twice. The physical separation was computed from the projected one assuming a distance modulus of 5.61 (Mermilliod et al. 1992). The mass of the components and the mass-ratio were obtained from the absolute JHK-magnitudes using Henry & McCarthy's (1993) M_{JHK}-mass relationships. The visual photometry and rotational velocities are from Stauffer & Hartmann (1987), Soderblom et al. (1993), and Queloz et al. (1996).

The Pleiades membership of the putative companions was assessed by plotting them in a J-(J-K) diagram where the primaries define the observational Pleiades ZAMS. Four secondaries (HII 120B, HII 347B, HII 890B, HII 915B) turned out to be background field stars. All other secondaries (and all of the primaries) are consistent with Pleiades membership from their location in the color-magnitude diagram. Two primaries (HII 303A, HII 738A) and one secondary (HII 1397B) appear to be shifted by about 0.8 mag above the Pleiades ZAMS and may therefore be photometric binaries. We lack multicolor photometry for 2 systems: HII 2881, a very close pair with a separation of less than 0.1″ and equal magnitude components, and therefore most certainly a physical binary, and HII 1348 with a faint companion at a distance of 1.09″, which we consider a background object pending further photometric measurements.

A K-(B-V) color-magnitude diagram for the whole sample is shown in Fig. 2. For binaries, the K-magnitude of the whole system is plotted. Binaries resolved in this survey are usually shifted above the Pleiades ZAMS and most were previously known as photometric binaries. The 2 systems that lie well beyond the equal-mass binary locus (located 0.75 mag above the Pleiades ZAMS) are HII 1397 and HII 303. As noted above, HII 1397B and HII 303A are suspected binaries from their location in the J-(J-K) color-magnitude diagram, so that both systems may in fact be triples. Fig. 2 also shows that some of the previously known photometric binaries are not resolved in our survey. Some of these are known spectroscopic binaries. A more detailed discussion of how these results compare with previous studies of binarity in the Pleiades is presented in Sect. 4.1.

The mass-ratio distribution is strongly peaked towards q=1 (see Table 1). This, however, merely results from an observa-

Table 1. Photometry and astrometry of Pleiades multiple systems

HII	Sep ($''$)	Sep (AU)	PA (deg)	J_A	H_A	K_A	ΔJ	ΔH	ΔK	M_A ($M_\odot$)	M_B ($M_\odot$)	q	V	B-V	vsini (km s^{-1})
Physical systems															
97	0.73	96	48.5	10.71	10.17	9.99	1.80	1.75	1.62	0.73	0.48	0.67	12.53	1.04	6.8
102	3.63	479	213.1	9.11	8.80	8.55	3.60	3.27	3.12	1.00	0.45	0.45	10.40	0.67	18.3
134	1.83	242	269.4	11.74	10.98	10.74	0.10	0.07	0.13	0.60	0.59	0.98	14.25	1.43	70.0
299†	5.69	752	307.7	10.01	9.55	9.38	0.21	0.10	0.09	0.83	0.81	0.98	10.74	0.84	6.3
303	1.81	239	336.4	9.32	8.80	8.60	0.10	0.33	0.29	0.97	0.94	0.97	10.36	0.84	17.4
357	0.50	66	70.0	10.97	10.35	10.16	1.84	1.75	1.64	0.69	0.42	0.61	13.20	1.17	10.0
571	3.93	518	65.8	9.67	9.32	9.13	4.64	4.36	4.09	0.89	0.18	0.20	11.14	0.74	6.8
738	0.50	66	157.3	9.89	9.29	9.00	2.41	2.28	2.18	0.89	0.53	0.60	11.18	0.79	55.0
870	0.51	67	309.0	9.93	9.42	9.17	4.41	3.82	3.73	0.87	0.21	0.24	11.05	0.73	9.7
885	0.87	115	201.8	10.42	9.96	9.79	0.78	0.60	0.50	0.76	0.67	0.87	11.96	0.98	5.2
1061	0.32	42	311.3	11.44	10.75	10.59	1.80	1.75	1.64	0.63	0.33	0.53	13.61	1.19	$<$10
1100	0.78	103	260.7	10.76	10.25	10.03	0.26	0.19	0.20	0.72	0.68	0.95	12.13	1.06	5.4
1182	1.14	150	219.9	9.29	9.00	8.83	5.54	5.09	4.79	0.96	0.15	0.16	10.34	0.60	16.4
1298	1.18	155	77.7	10.46	9.98	9.84	3.01	2.78	2.68	0.76	0.29	0.38	12.21	0.96	4.8
1355	1.26	166	307.7	11.44	10.75	10.53	0.74	0.77	0.70	0.63	0.54	0.85	13.90	1.36	12.5
1397†	6.26	826	263.0	7.13		7.03	1.44		1.08	1.8:	1.2:	0.67:	9.10	0.59	15.7
1553	0.09	12	5.1	10.40	9.91	9.68	1.13	0.77	0.84	0.78	0.63	0.82	12.37	1.06	12.0
2027	0.10	13	73.8	10.12	9.61	9.47	0.15	0.19	0.10	0.82	0.80	0.97	10.81	0.81	5.6
2106	0.32	42	31.0	10.04	9.63	9.48	2.49	2.14	2.04	0.82	0.50	0.61	11.42	0.83	8.0
2193	0.69	91	277.3	11.64	10.94	10.74	1.77	1.81	1.71	0.61	0.29	0.48	14.11	1.33	23.0
2278	0.37	49	178.9	10.12	9.64	9.44	0.09	0.08	0.05	0.82	0.81	0.98	10.82	0.83	7.7
2500 AB†	6.84	903	55.4	9.05	8.80	8.65	0.29:	0.11:	0.04	1.00	0.98	0.98	10.83	0.60	33.0
2500 AC	0.53	70	258.3	9.05	8.80	8.65	2.07	1.66	1.69	1.00	0.67	0.67	10.83	0.60	33.0
2881	0.08:	11:	150:			9.75:			0:	0.77:	0.77:	1.00:	11.57	0.97	7.8
3197 AB	0.11	15	233.1	10.56	10.05	9.91	0.34	0.26	0.16	0.74	0.70	0.95	11.98	1.03	20.1
3197 AC	0.60	79	311.2	10.56	10.05	9.91	1.34	1.14	1.09	0.74	0.57	0.77	11.98	1.03	20.1
MT 61 AB	1.56	206	277.2	11.92	11.29	11.01	1.37	1.35	1.31	0.57	0.32	0.56	15.15	1.45	$<$10
MT 61 AC	1.57	207	273.9	11.92	11.29	11.01	1.50	1.51	1.34	0.57	0.30	0.52	15.15	1.45	$<$ 10
Projected systems (background field secondaries)															
120	3.80		121.9	9.46	9.14	9.01	6.18	6.00	6.14	0.92			10.72	0.66	9.4
347	4.61		338.4	10.92	10.22	10.04	3.76	3.86	3.95	0.71			13.88	1.37	65.0
890	1.74		198.4	11.73	11.06	10.85	4.86	5.11	5.41	0.59			14.59	1.34	5.4
915	5.32		118.9	11.25	10.57	10.41	4.71	4.88	4.99	0.66			13.67	1.19	12.0
1348	1.09		347.9			9.59			5.47	0.80			12.58	1.10	5.1

":" denotes uncertain measurements

† HII 299B = HII 298, HII 1397B = HII 1392, HII 2500B = HII 2503

Dereddened V, B-V, and $v\sin i$ are from Stauffer & Hartmann (1987), Soderblom et al. (1993), and Queloz et al. (1996).

Table 2. Binary frequency

Sep. range	0.08-0.3	0.3-0.5	0.5-1.0	1.0-2.0	2.0-6.9	$''$
ΔK_{max}	2.0	3.5	5.0	6.0	6.5	mag
q_{min}	0.60	0.25	0.14	$<$0.1	$<$0.1	
$N_{detect.}$ $[q_{min}, 1.0]$	4	4	8	7	5	
$N_{undetect.}[0.1, q_{min}]$	11.0	1.3	0.5	0	0	
N_{tot}	15.0	5.3	8.5	7	5	
Semi-major axis	14-50	50-83	83-166	166-332	332-1150	AU
log P_{orb}	4.2-5.1	5.1-5.4	5.4-5.8	5.8-6.3	6.3-7.1	days
Pleiades B.F. (rms)	10.4 (2.7)	3.7 (1.6)	5.9 (2.0)	4.9 (1.8)	3.5 (1.6)	%
Field B.F	9.5	3.1	4.0	4.6	6.1	%

tional bias since it is easier to detect bright than faint companions, in particular close to the primary (see below). For systems with separations larger than 0.15″, the q-distribution is flat. Accounting for the detection bias against faint, i.e., low-mass, companions, we believe that the observed mass-ratio distribution is consistent with the q-distribution of field G dwarfs binaries derived by Duquennoy & Mayor (1991). None of the companions detected during the Pleiades survey is found to lie below the hydrogen-burning mass limit.

3.1. Binary frequency

We detected 22 binary systems and 3 triples over the 144 G and K stars surveyed in the Pleiades, yielding 28 orbits with a projected separation from 0.08″ to 6.9″ (11-910 AU). We cannot rule out that the widest systems are not physical ones but consists instead of two unbound Pleiades members, though Duquennoy & Mayor (1991) suggests a cut-off separation of more than 2000 AU for the gravitational binding of binary systems with solar-mass primaries, which is twice as large as the maximum projected separation observed here. In order to compare the binary frequency found among the 100 Myr-old Pleiades G and K dwarfs to that derived for the Gyr-old G and K dwarfs of the field (Duquennoy & Mayor 1991, hereafter DM91, Tokovinine 1992, Fisher & Marcy 1992), we first have to correct our detection rate for observational biases and then to convert the distribution of projected separations into a distribution of orbital periods.

Observational biases arise from our inability to detect faint companions next to the bright primaries. The largest magnitude difference we can detect between the primary and the secondary, ΔK_{max} , depends upon the projected separation of the system: the larger the separation, the easier the detection of faint companions. We empirically estimated ΔK_{max} as a function of separation by computing the (3σ) rms noise from the actual images at increasing distances from the primary. The resulting curve is shown in Fig. 3. At small separations, $\rho \leq 0.2''$, the faint companion is diluted into the bright PSF of the primary and is not seen if fainter than the primary by more than 2.0 magnitudes. At larger separations, however, ΔK_{max} rapidly increases to 5 magnitudes at 0.5″, and up to 7 magnitudes at 2″. The binary systems listed in Table 1 are overplotted in Fig. 3 and suggest that we might have slightly overestimated our ability to detect faint companions at a separation less than 0.2″ from the primary.

How many binaries have we missed due to this detection bias? We address this issue in the following way: for a given ΔK_{max}, we compute the corresponding mass-ratio below which we cannot detect the companion and then use the mass-ratio distribution of late-type field binaries to derive the number of systems we missed. In order to proceed, we first divided the 0.08-6.9″ separation range into 5 intervals, each of which is associated with an average ΔK_{max} listed in Table 2. In each interval of separation, ΔK_{max} is converted into the corresponding mass-ratio, q_{min}, using Henry & McCarthy (1993) M_K-Mass relationship and assuming an average M_K= 4.0 (0.8 $M_\odot$) for the primary. The resulting value of q_{min} is listed in Table 2. Not surprisingly, it is seen that in the lowest separation bin (0.08-0.3″)

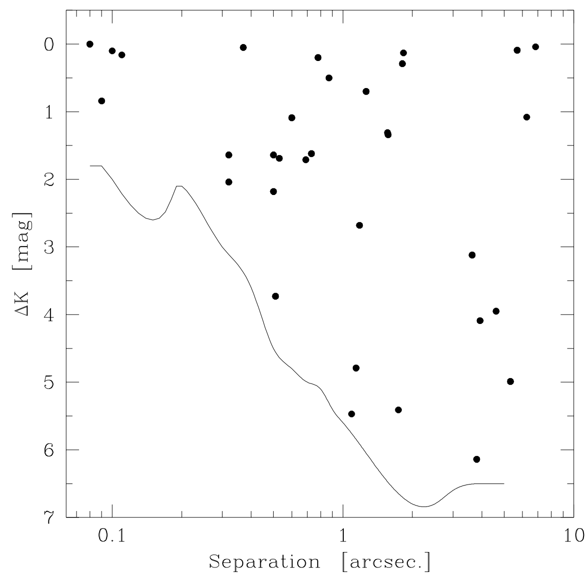

Fig. 3. Completeness limit. Solid curve: largest detectable magnitude difference in the K-band between the primary and the secondary as a function of the projected separation of the system. The curve was computed from 3σ noise measurements in actual images. The ripples seen at low separation ($\leq$ 0.4″) correspond to the succession of Airy rings from the PSF of the primary. At the largest separations ($\geq$ 3.0″) the step-like decrease in ΔK_{max} results from our acquisition procedure (see Sect.2.). Binary systems detected during the survey are overplotted (solid dots).

we can only detect relatively massive companions. At larger separation, however, mass-ratios as low as 0.2 and below are detected.

We use the distribution of mass-ratios derived by DM91 for field binaries with a G-type primary in order to estimate from q_{min} how many systems we have missed in our survey (i.e., how many systems are expected to have a mass-ratio between DM91's mass-ratio detection limit of 0.1 and our detection limit of q_{min}). By doing so, we assume that the mass ratio distribution of Pleiades binaries is similar to that of G-type dwarf binaries of the field. The number of detected and undetected systems is listed in Table 2. Because we reach very low-mass ratios at angular separations larger than 0.3″, we detected virtually all systems beyond that separation. However, at lower separations, the correction for incompleteness is important and its accuracy depends upon the validity of the assumed q-distribution.

The 6^{th} line of Table 2 lists the total (detected + undetected) number of systems in each bin of separation. In order to compare the Pleiades binary frequency to that of field dwarfs, we next translate projected separation into orbital periods. This is done in two steps. Firstly, we convert distribution of projected separations into a distribution of true semi-major axes. Assuming random inclination of the orbital planes, various authors have addressed this issue, usually through Monte Carlo simulations. The statistical relationship between the semi-major axis, a, and the projected separation, ρ, takes the form: $<\log a> = <\log \rho> + \log c$ where $\log c$ is a constant whose value has been estimated to 0.1 (DM 91, Fisher & Marcy 1992, Reipurth & Zinnecker 1993). We used this relationship and a distance modulus of 5.61 (Mermilliod et al. 1992) to convert the projected separations into semi-major axes (Table 2). Secondly, we converted semi-major axes into orbital periods using Kepler's third law, adopting an average system mass of 1.3 $M_\odot$ (the binary sample yields $<M_{tot}>$ = 1.3 ± 0.4). The range of semi-major axes and of orbital periods corresponding to the 5 intervals of projected separations we have considered are listed in Table 2.

Finally, the binary frequency (number of binary orbits/number of stars in the sample) we derive for Pleiades dwarfs in each interval of orbital periods is listed in Table 2 and compared to that of G-type field binaries. The latter was computed from the gaussian distribution of orbital periods reported by DM91. Comparison of the last 2 lines of Table 2 indicates no significant difference between the binary frequency among Pleiades dwarfs and among field dwarfs in any of the orbital period intervals. The results are illustrated in Fig. 4 where the distribution of the orbital periods of Pleiades *spectroscopic* binaries (Mermilliod et al. 1992) are also shown. We find that not only the overall binary frequency over the orbital period range log P=4.2-7.1d is the same in the Pleiades (28±4%) and in the field (27%) but also that the distribution of orbital period is similar in both samples. The similitude further extends to shorter orbital periods as Mermilliod et al. (1992) found the same frequency of spectroscopic binaries with a period shorter than 1000 days in the Pleiades (13%) and in the field (12%).

We thus conclude that the binary frequency as well as the distribution of orbital periods among G and K dwarfs does not evolve from the age of the Pleiades (100 Myr) to the age of field stars (a few Gyr).

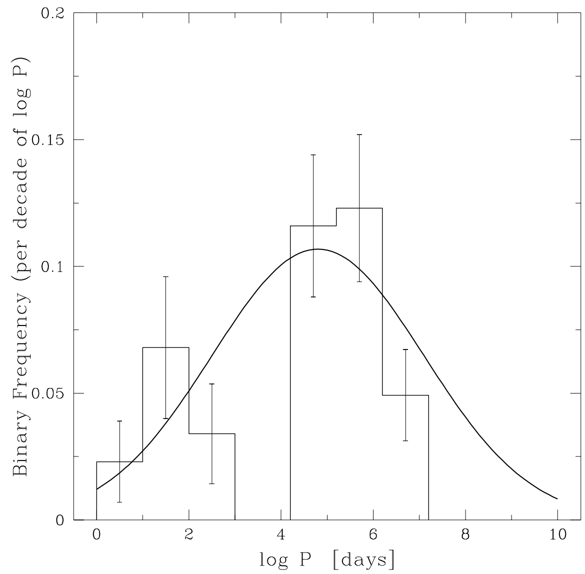

Fig. 4. Frequency distribution of binaries as a function of orbital period. The gaussian curve indicates the frequency of binary per decades of log P for G-type field dwarfs (from DM 91). The left histogram shows the frequency of spectroscopic binaries in the Pleiades with periods less than 1000 days (from Mermilliod et al. 1992). The right histogram illustrates the frequency of close binaries found in the present survey. Note that the first bin of this histogram corresponds to a domain of angular separations where the correction for incompleteness in important (see 3.1), a source of uncertainty which is not included in the Poisson error bar. Comparison between the curve and the histograms indicates that both the overall binary frequency and the distribution of orbital periods are the same in Pleiades G-K dwarfs and field dwarfs.

3.2. Binarity and rotation

Fig. 5 shows the distribution of $v\sin i$ for single and binary stars of the sample. Note that the $v\sin i$ measurement refers to the primary as the $v\sin i$ of the secondary is usually unknown. The $v\sin i$ distribution of G and K dwarfs of the Pleiades is known to be strongly weighted towards slow rotators with a wide but sparsely populated tail of fast rotators (Stauffer & Hartmann 1987, Soderblom et al. 1993, Allain et al. 1996, Queloz et al. 1996). Fig. 5 shows that this is true of both single and binary stars. Like single stars, only a few of the primaries of binary systems are fast rotators. Indeed, we find that within statistical uncertainties the *fractional number* of binaries is the same among the slow and fast rotator groups. This result holds regardless of the adopted borderline between slow and fast rotators (10, 20, 30, 50 km s^{-1}). There thus seems to be no relationship between rotation and binarity in this sample.

Conceivably, the impact of a companion star on the circumstellar disk of the primary and, therefore, on its rotational evolution, will strongly depend upon the system separation and mass-ratio. A low-mass remote companion may not significantly affect the evolution of the circumprimary disk while, on the opposite, a massive and very close companion will produce a strong tidal disturbance. Therefore, a connection between binarity and the rotational evolution of the primary may only appear when both the separation and mass-ratio of the systems are taken into account. Fig. 6 shows the $v\sin i$ of the primaries as a function of system's separation and mass-ratio. In the framework of current models of PMS angular momentum evolution, primaries belonging to the closest systems with massive companions are expected to have spun up during their PMS evolution as their circumstellar disk was truncated and rapidly dissipated due to the tidal effect from the companion. One would therefore expect such primaries to be fast rotators on the ZAMS. Four systems in our sample have a projected separation of less than 20 AU and large mass-ratios. Yet, none of the primaries of these systems are rapid rotators (Fig. 6). At larger separations, both slow and fast rotators are found among primaries regardless of the systems' separation and mass-ratio. In any range of semi-major axes, the $v\sin i$ distribution of the primaries is in fact consistent with that of single stars. We thus conclude that the presence of a companion star has no effect on the PMS rotational evolution of the primary and discuss the implications of this result in Sect. 4.3.

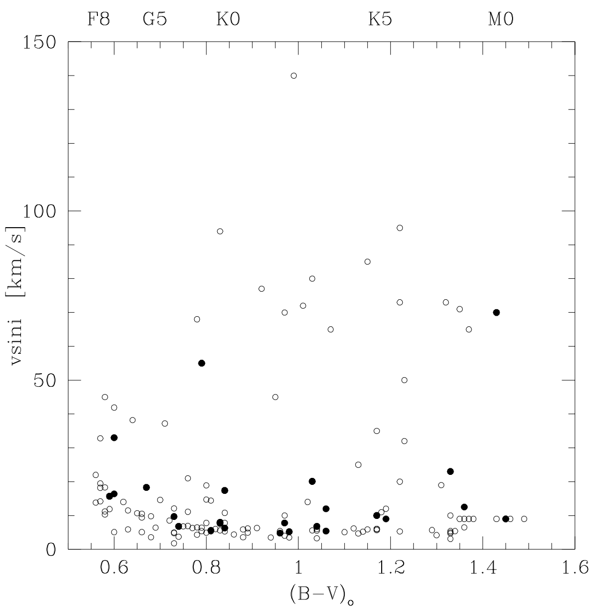

Fig. 5. Projected rotational velocity ($vsini$) as a function of $(B-V)_o$. "Single" stars are shown as empty dots, multiple systems as filled ones. Stars with $(B-V)_o$ larger than 1.3 and plotted at $vsini$ = 9 km s^{-1} only have $vsini$ upper limits of 10 km s^{-1} .

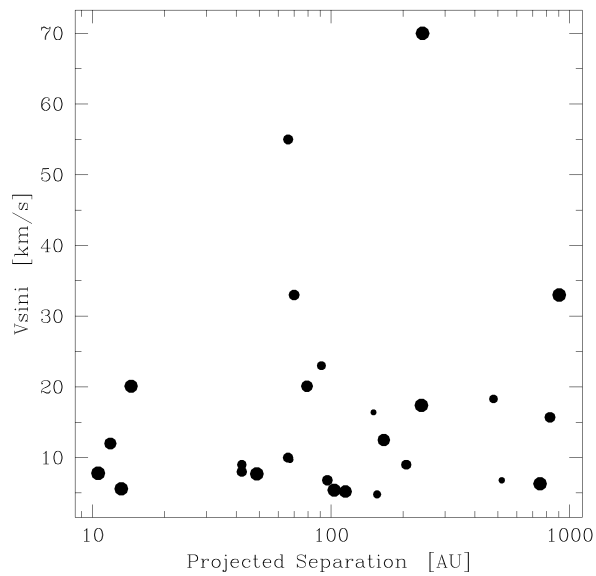

Fig. 6. Primary's rotational velocity ($vsini$) as a function of projected separation of the binary systems. Symbol size is proportional to the mass-ratio

4. Discussion

4.1. Comparison with previous photometric and spectroscopic studies

Pleiades is one of the most extensively studied young open clusters. Here, we will limit the comparison of our results with only the most recent studies relevant to cluster binaries, namely: Mermilliod et al.'s (1992) spectroscopic survey and Stauffer's (1984) photometric one. A complete table (Table 3) including the K-photometry of all primaries we have observed during the survey is available in electronic form at CDS Strasbourg. Table 3 contains proper reference to previously known binaries, either spectroscopic, photometric or visual.

Mermilliod et al. (1992, MRDM) conducted a radial velocity survey of Pleiades G and K stars to investigate the frequency of spectroscopic binaries in the cluster. They concluded that the frequency of low-mass spectroscopic binary is the same in the Pleiades and in the field. There are 63 stars in common between their survey and ours and we compare below the results of the two surveys.

"Single" stars: 41 stars of the common sample were reported as "single" by MRDM. One (HII 1182) is found here to be a binary with a large flux ratio (ΔK = 4.8) and a relatively large separation (1.14″) which explains why MRDM did not detect it as a spectroscopic binary. Another one (HII 2106), is a close binary (0.32″) with a flux ratio of about 2 magnitudes in the K-band. This sytem probably has too long an orbital period and too small orbital velocity variations to have allowed its detection as a spectroscopic binary. The 39 remaining "single" stars reported by MRDM are not resolved either in our survey.

SB1: 8 other stars common to the 2 samples are reported to be SB1 by MRDM. Because all have orbital periods less than 1000 days, none of these is expected to be resolved in our survey. One of the SB1 (HII 571), however, is found here to be part of wider system with a large flux-ratio, which suggests that it might in fact be a triple system.

SB2: 3 of the SB2 detected by MRDM are included in our survey. Two have short orbital periods (HII 173, HII 1117) and are therefore undetectable at our resolution. The third, HII 2147, was reported as a tentative SB2 candidate with a period longer than 6000 days. Although it may lie in the detectable range of our survey, we found no companion to this star.

Triple systems: MRDM list HII 303/302 and HII 2027 as being triple systems. Both were observed during our survey. HII 303 is a visual binary (see below) and its JHK photometry suggests that HII 303A is itself a binary. With the addition of HII 302 which lies 18.3″ away (MRDM), this might be a quadruple system. HII 2027 is a particularly interesting system. MRDM found that it is a triple consisting of an SB1 with an orbital period of 48.626d, which is itself a component of a larger SB2 system for which MRDM have an incomplete radial velocity curve which indicates a period of more than 3000d. The wider SB2 is resolved in our survey with a projected separation of 0.1″, i.e., 13 AU at the distance of the Pleiades. If close to the true semi-major axis, the measured separation suggests an orbital period of about 38 years (14000d). It may thus be possible on a timescale of about 10 years to trace a significant portion of the system's visual orbit which, combined with the radial velocity curves, would lead to a direct estimate of the mass of the components.

Photometric and visual binaries: we observed 12 photometric and 2 visual binaries listed in MRDM. The 2 visual binaries

(HII 299/298, HII 303) are easily detected and have the same separation than reported by MRDM and a K-flux ratio consistent with that expected from the V-band flux ratio they quote. Of the 12 photometric binaries listed in MRDM and included in our sample, 8 have been spectroscopically monitored by MRDM. Because no radial velocity variations are detected, these systems must have long orbital periods ($\geq$1000d). And since they are reported as photometric binaries they must have large mass-ratios. Only 4 are resolved here (HII 102, HII 885, HII 2278, HII 2881). This low detection rate suggests that most of the remaining photometric binary (HII 174, HII 186, HII 248, HII 476, HII 708, HII 923, HII 975, HII 1136) may lie in a separation range covered neither by spectroscopic studies nor by the present survey, i.e., between about 5 and 10-15 AU. HII 975 and HII 1136, as well as HII 476, lie in or near the region of the Merope CO cloud, and their classification as photometric binary may merely results from their heavily reddened colors (see Stauffer 1984).

A better detection rate of previously known photometric binaries is obtained when comparing our results with those of Stauffer's (1984) photometric survey of the cluster. Stauffer (1984) reported 42 unresolved photometric binaries in a sample of 154 Pleiades late-type dwarfs on the basis of their location above the observed Pleiades ZAMS in the color-magnitude diagram, a fraction that he found consistent with the frequency of low-mass binaries in the field. Of these, we observed 20 and resolved 15. Among the 5 unresolved systems (HII 173, HII 625, HII 1039, HII 1136, HII 3187) at least one (HII 173) is a spectroscopic binary (MRDM) and 4 were not included in MRDM spectroscopic survey. Conversely, our survey includes 92 stars photometrically studied by Stauffer (1984) and Stauffer & Hartmann (1987) for which they found no indication of binarity. Of these, 4 are found here to be binaries (HII 97, HII 1061, HII 1298, HII 2193).

Overall, we have spatially resolved most of the photometric binaries included in our survey as well as one previously known spectroscopic binary whose orbital period and mass-ratio lie within our detection limits. In addition, we have detected 9 multiple systems which were not previously known either as spectroscopic or photometric binaries.

4.2. The formation and evolution of young multiple systems

Because Pleiades G and K dwarfs have only recently completed their PMS contraction to the ZAMS, the comparison of their binary frequency with that of young PMS T Tauri stars (TTS) provides insight into the evolution of binary systems during the pre-main sequence. In the last years, extensive surveys of TTS binaries have been completed, with somewhat puzzling results whose interpretation is still debated (see Mathieu 1994 for a review). On one hand, independent surveys of the Taurus-Auriga and Ophiuchius dark clouds have revealed a frequency of low-mass TTS binaries which is 2 to 4 times larger than that observed in late-type dwarfs in the semi-major axis range from 15 AU to 1800 AU (Leinert et al. 1993, Ghez et al. 1993, Simon et al. 1995). These results point to a statistically significant (2.5σ) overabundance of PMS binaries compared to main sequence (MS) ones. Another survey of PMS stars in several southern dark clouds similarly points to an excess of binary systems, though at a level not as significant as in the Tau-Aur association (Reipurth & Zinnecker 1993). On the other hand, Prosser et al. (1994) more recently found the binary frequency among the PMS population of the Orion Trapezium cluster to be the same as that observed among field dwarfs. However, because Prosser et al. did not correct they survey for incompleteness, the binary frequency they derive is to be considered as a lower limit. Brandner et al. (1996) also found a relatively low frequency of binaries, similar to that of field stars, from a diffraction-limited survey of the PMS populations of the Sco-Cen OB2 association and of the Chameleon and Ophiuchius dark clouds.

The early and converging findings of a large excess of PMS binaries in the Tau-Aur association compared to field binaries led to the suggestion that the number of multiple systems drastically decreases during PMS evolution. Ghez et al. (1993) proposed that this evolution results from the disruption of triple and quadruple systems before they reach the main sequence. Yet, Leinert et al. (1993) found the hierarchy of multiplicity to be the same in PMS and main sequence stars, which casts doubt upon this interpretation. Alternatively, Reipurth & Zinnecker (1993) suggested that the overall fraction of PMS binaries might be the same as for MS binaries but that the distribution of orbital periods differs. The apparent excess of PMS binaries with semi-major axes between 18 and 1800 AU would then imply a corresponding deficiency of PMS binaries in other ranges of semi-major axes. However, the frequency of *spectroscopic* binaries appears to be the same in low-mass PMS stars and field dwarfs (Matthieu 1994). Moreover, both Reipurth & Zinnecker (1993) and Leinert et al. (1993) argued that within the separation range they have studied the distribution of orbital periods of PMS binaries is consistent with the log-normal distribution of orbital periods observed for MS binaries (DM 91). Hence, the apparent excess of PMS binaries within the 18-1800 AU separation range in the Taurus-Auriga cloud, and perhaps in other star forming regions as well, points to a real overall excess of PMS binaries compared to field ones.

Our results on the Pleiades indicate that both the binary frequency and the distribution of semi-major axes of Gyr-old field binaries is already present at the age of the Pleiades. This implies that *if* the number or the distribution of semi-major axes of PMS binaries has to evolve in order to match the binary frequency of field dwarfs, this evolution has to be completed in less than 100 Myr. This time span appears much too short either to allow about half of the systems to be disrupted by gravitational encounters in such a low stellar density region as Taurus-Auriga (Clarke & Pringle 1991) or to yield a drastic change in the distribution of orbital periods. Pringle (1991) and Artymowics & Lubow (1994) argued that the closest PMS binary systems are surrounded by a circumbinary disk. They showed that in such a case, orbital angular momentum is transferred from the binary to the disk through tidal effects on a timescale comparable to their PMS evolution. As orbital angular momentum is lost by the system, its semi-major axis decreases, thus allowing for an evolution of the orbital period distribution on a relatively short timescale. However, we argue below that accretion still occurs from the circumbinary disk onto the central system (Lubow & Artymowicz 1996, Bate & Bonnell 1996). Such an inward transfer of angular momentum from the disk onto the system then reduces, and perhaps balances, its orbital evolution. It thus appears very unlikely that an evolution of either the fractional number or the orbital properties of PMS binaries can account for the much lower number of binaries observed in the Pleiades.

There is an important difference between the Taurus-Auriga dark cloud and the Pleiades cluster: the former is a loose T association with a density of about that 2 star pc^{-3} in stellar aggregates (Gomez et al. 1993), while the latter must have been a dense cluster at the epoch of its formation, perhaps as dense as the Orion Trapezium cluster (2200 stars pc^{-3}, Herbig & Terndrup 1986). We believe that the very different environments under which star formation has taken place in the Tau-Aur cloud and in the protocluster that led to the Pleiades may be responsible for their widely different binary content, as previously suggested by Prosser et al. (1994) for the Orion Trapezium cluster.

Theoretical studies support the idea that the formation and survival time of protobinaries may depend upon environmental conditions, and in particular on the local stellar density. If, as suggested by recent numerical computations (Bate et al. 1995), binaries with a semi-major axis in the range investigated here form through disk fragmentation during the protostellar collapse, the binary frequency is expected to be tightly linked to the survival time of massive protostellar disks. Clarke & Pringle's (1991) (see also Ostriker 1994, Sterzik & Durisen 1995) ran numerical computations of dissipative encounters between protostars, taking into account the presence of their disk, and showed that few of these interactions lead to the formation of a bound system by capture. Instead, most of the encounters result in the truncation and possibly dissipation of the circumstellar disks, in part due to the enhanced accretion rate which results from tidal torques experienced during the encounter. Since the rate of encounters is proportional to the stellar density, disk disruption through this process is expected to be more important in dense clusters. In a similar vein, Larson (1995) suggested that protostellar encounters could be efficient in disrupting protobinary systems in well-populated protostellar clusters. Clarke & Pringle estimated that the rate of such disruptive encounters is of the order of 0.13 Myr^{-1} in regions like the Orion Trapezium ($n \simeq 10^4$ pc^{-3}, see also Herbig & Terndrup 1986) and only 0.00013 Myr^{-1} for stellar densities of 12 pc^{-3} more representative of T Tauri associations like Taurus. Ostriker (1994) obtained similar results and concluded that enhanced accretion due to gravitational encounters does not significantly contribute to the dispersal of circumstellar disks except in the densest protoclusters.

Gravitational encounters between protostars and protobinaries are thus expected to decrease the number of binaries in dense protoclusters in two ways. Firstly, by truncating or dissipating the protostellar disks from which protobinaries form. Secondly, by enhancing the disruption rate of protobinaries that have formed. Even though the rate of gravitational encounters computed from numerical simulations still appears perhaps too low to account for a factor of 2 difference in the fraction of PMS binaries between e.g. Taurus and the Orion Trapezium cluster (Clarke & Pringle 1991), one may qualitatively expect less binary systems to form and survive in clusters than in low-density associations. This would then naturally account for the higher binary fraction observed in Taurus-Auriga association compared to that of the Orion Trapezium cluster (Prosser et al. 1994), the Pleiades (this study), and the Hyades (Gizis & Reid 1995), which are or have been dense protoclusters. Additional, though marginal, support to this interpretation comes from the recent survey of the Scorpius-Centaurus OB association by Brandner et al. (1996) who found a trend for a decreasing binary frequency in regions of enhanced stellar density, although the density contrast between the various regions they surveyed is not as pronounced as between protostellar clusters and T associations.

We conclude that the low binary content of the Pleiades compared to the large number of PMS binaries in the Taurus-Auriga cloud is not the result of an evolutionary process. Instead, it reflects the different outputs of the two modes of star formation proposed by Lada et al. (1991, 1993), clustered and isolated. In other words, the binary content of PMS populations is set at the very epoch of star formation and does not evolve further during PMS and MS evolution. If this interpretation is correct, the implication is that most field dwarfs were born in dense protostellar clusters and not in T associations (Lada et al. 1991, Prosser et al. 1994, Larson 1995).

While the statistical properties of Pleiades binaries offer some insight into the process of binary formation and evolution, the detailed structure of a few systems may be of special interest to those who model the formation of multiple systems. In particular, the 2 compact triple systems detected during the survey exhibit quite opposite properties. The first one, HII 3197, consists of two 0.7 $M_\odot$ stars with a projected separation of 15 AU and a third, 0.6 $M_\odot$ star 79 AU away. This triple system is in fact strikingly similar to the output of Bate et al's (1995) smooth particle hydrodynamics (SPH) computations of the fragmentation of an isothermal cloud. The other system, MT 61, consists of two 0.3 $M_\odot$ stars with a projected separation of 11 AU and a third, 0.6 $M_\odot$ star 206 AU away. That these two triple systems display such opposite properties, at least as far as the mass-ratio between the close double and the tertiary is concerned, may provide an interesting challenge for formation models (see also Mermilliod et al. 1994).

4.3. Binarity, rotation and the lifetime of circumstellar disks

A relationship between binarity and rotation in late-type ZAMS dwarfs is expected on the following premisses. On one hand, recent modelling of the angular momentum evolution of PMS stars and measurements of their rotation rates suggest that the rotational evolution of low-mass PMS stars is largely dictated by the interaction between the star and its circumstellar disk. The presumably magnetic interaction between the star and the disk results in the braking of the star, and prevents it from spinning up as it contracts towards the ZAMS (Königl 1991). Thus long-lived disks will lead to slowly rotating stars on the ZAMS, while short-lived disks will acount for the tail of fast ZAMS rotators (Bouvier et al. 1993). On the other hand, the presence of a nearby companion is expected to affect the structure of the circumstellar disk of the primary and to shorten the duration of the accretion phase (Artymowiz et al. 1991). The primary in such systems would thus have time to spin up and reach the ZAMS as a fast rotator. If these two current ideas are correct, one would then expect a larger fraction of binary systems among fast ZAMS rotators than among slow ones.

We did not find any evidence for such a relationship between binarity and rotation in our sample. As stated above (Sect. 3.2) we find the same fraction of binaries among slow and fast rotators of the Pleiades. The distribution of $v\sin i$ among primaries of binary systems is the same than among single stars of the Pleiades within 1σ statistical uncertainties. We argue below that this result indicates that the accretion process in PMS binary systems goes unimpeded by the presence of the companion.

The structure of a disk around a binary system can take several configurations depending primarily upon the system semi-major axis compared to the size of the disk. For binaries with a semi-major axis much smaller than the disk radius, the inner disk is truncated by resonant interaction. A circumbinary (CB) disk results whose inner edge lies at about 2 semi-major axes from the central system (e.g., Artymowicz & Lubow 1994). This has probably been the case for the 4 closest systems in our sample with (projected) separations between 10 and 15 AU and mass-ratios close to unity (see Fig. 6). The progenitors of these binaries most likely were PMS systems similar to the T Tauri binary GG Tau whose circumbinary disk has been imaged at both millimetric and near-infrared wavelengths (Dutrey et al. 1994, Roddier et al. 1996). In early SPH simulations, Artymowics (1992) found that the inner circumbinary disk is completely depleted and does not interact with the central binary. In such a case, the two components of the binary should spin up and reach the ZAMS as fast rotators. Yet, the primaries of the 4 closest Pleiades systems are all slow rotators with $v\sin i$ less than 20 km s^{-1}. According to models of PMS angular momentum evolution, these slow rotation rates indicate instead that accretion has occurred on the surface of the primaries for a large fraction of their PMS evolution, perhaps up to 10 Myr (e.g. Bouvier & Forestini 1995, Keppens et al. 1995). Since the CB disk is the only large reservoir of material available in these systems, this implies that accretion must have occurred from the CB disk onto the central system. More recent SPH simulations by Lubow & Artymowicz (1996) showed that inward gas streams originating from the CB disk could in fact flow across the tidal gap onto the central stars if the internal gas pressure in the CB disk is large enough to overcome the energy barrier of the resonance. The slow rotation rates of the Pleiades primaries support this view, though it must be noted that the braking of the central star through its magnetic interaction with the disk has only be modelled for circumstellar accretion disks. It remains to be seen whether magnetospheric accretion of the (non-keplerian) gas streams originating from the circumbinary disk leads to the same braking process. This could be the case for instance if the free-falling material from the CB disk formed a gazeous circumstellar ring around the primary extending beyond its magnetospheric radius (i.e., a few stellar radii).

It is in the semi-major axes range from a few times 10 AU to 100 AU that the tidal effect of the companion is expected to be the strongest on the circumprimary disk. For such binaries with a semi-major axis of the order of the disk radius, each component of the system possesses its own circumstellar (CS) disk whose outer edge, however, is truncated by the tidal effect from the other component (e.g. Artymowics & Lubow 1994). Because the two CS disks contain only a fraction of the mass of the initial disk, their lifetime is expected to be shorter than those of CS disks around single stars. Moreover, the circumprimary disk experiences gravitational torque from the orbiting secondary which leads to an enhanced mass-accretion rate, further reducing the disk lifetime (e.g. Papaloizou & Terquem 1995, Korycansky & Papaloizou 1995). Alternatively, Armitage & Clarke (1996) have suggested that the combined effects of magnetic torques exerted on the inner disk by the stellar magnetosphere and tidal truncation of the outer disk by the companion in close binary systems would in fact prolong the lifetime of a circumstellar ring of dust and gas around the primary. They consequently predict that the primary should remain in slow rotation in such systems.

There are 12 systems in our sample whose projected separation lies between 40 and 100 AU, the usually assumed radius of CS disks around single PMS stars (Bertout 1989). The progenitors of these systems probably were two PMS stars and their associated truncated circumstellar disks. Again, because disk truncation and tidal effects internal to the system are expected to shorten the duration of the accretion process on the central stars, one would expect them to exhibit significant rotation rates at the age of the Pleiades. Fig. 6 shows that a couple of the primaries in these systems have velocities in excess of 30 km s^{-1}. According to Bouvier & Forestini's (1995) model, this translates into a disk lifetime of 1 Myr or less. However, many of the primaries in this separation range have velocities of 10 km s^{-1} or less, indicative of a disk lifetime of about 10 Myr, i.e. of the order of the longest disk lifetime observed for single PMS stars.

Clearly, there is no direct relationship between binarity and rotation in our sample. In any separation range from 10 AU to 1000 AU, there is statistically the same frequency of binaries among slow and fast ZAMS rotators. In other words, the binaries are neither preferentially faster nor systematically slower rotators than single stars. Insofar as $v\sin i$ is correctly used as a diagnostic of the duration of the accretion process in PMS stars, this indicates that the disk lifetime is not affected by the presence of a companion, regardless of the separation and mas-ratio of the system. For very close binaries, this implies that accretion must proceed from the circumbinary disk onto the central system. For wider binaries, this implies that the truncated CS disks must be resplenished by an external reservoir of material. These results agree with the study of IR excesses among single and binary PMS stars by Simon & Prato (1995). They found no statistical differences in the lifetime of optically thick disks around single and binary stars. Moreover, investigating the properties of both components of PMS binaries, Prato & Simon (1996) found that hybrid systems consisting of an accreting classical T Tauri star and a non-accreting weak-line T Tauri star are very rare. They concluded that the CS disks of both components must disappear simultaneously and suggested that this occurs because both disks are fed by a common circumbinary envelope surrounding the whole system. Such a massive CB envelope resplenishing the truncated CS disks would allow for longer CS disk lifetimes and thus also account for the slow rotation rates of the Pleiades primaries in systems with intermediate separations.

While Simon & Prato 10μm excess study is sensitive to the inner disk regions from which the near-IR excess arises, the rotational velocity on the ZAMS depends upon the whole duration of the accretion process and, therefore, on the total disk/envelope mass (Cameron et al. 1995). The results on the Pleiades thus confirm and expand onto Simon & Prato's conclusion by suggesting that not only the inner disk regions but the survival time of the whole reservoir of material available for accretion onto the stars, either CS or CB, is not affected by the presence of a nearby companion, even though the structure of the disk is, as evidenced by e.g. the lower sub-mm flux exhibited by close PMS binaries compared to single stars (Jensen et al. 1994). We thus concur with the conclusion drawn by Simon & Prato from a different approach that the development of gaps in the inner disk and/or the truncation of the circumstellar disks does not prevent accretion to occur on the central stars of binary systems on a timescale similar to that of accretion from massive CS disks on single stars.

5. Conclusion

The relatively low binary frequency reported here for the Pleiades G and K dwarfs suggests that the formation and survival of binary systems depend upon environmental conditions. Fewer protobinaries seem to form and/or survive in dense environments such as protostellar clusters than in low-density star forming regions like Taurus. A possible mechanism to explain the influence of protostellar density onto the frequency of binary systems are disruptive gravitational encounters between protostars and their associated disks. The number of disruptive encounters scales with stellar density and is thus expected to be enhanced in high density star forming regions. This would qualitatively account for the lower binary frequency found in the Orion Trapezium cluster (Prosser et al. 1994), in the Pleiades, and in the Hyades (Gizis & Reid 1995) compared to that observed in the Taurus-Auriga cloud (Ghez et al. 1993, Leinert et al. 1993). If environmental conditions indeed play a major role in the formation and survival of protobinary systems, the similar binary frequency observed for Pleiades and late-type dwarfs of the field would imply that most field dwarfs were formed in dense protostellar clusters (Lada et al. 1991).

Judging from the rotational properties of Pleiades single and binary dwarfs, the pre-main sequence evolution of rotation in binary and single stars appears similar. Because the angular momentum evolution of young stars is thought to be intimately linked to the accretion process from a circumstellar disk, this result suggests that the existence of a companion does not significantly affect disk accretion and disk lifetimes. That several very close PMS binaries consists of 2 stars actively accreting from their disk (e.g., GW Ori, GG Tau, NX Pup, Mathieu 1991, Prato & Simon 1996, Roddier et al. 1996, Brandner et al. 1995), provides further and independent evidence that close companions do not prevent accretion from occurring on the primaries over a significant part of their PMS evolution.

Acknowledgements. JB thanks J. Pringle for his early suggestion to search for a possible link between binarity and rotation among ZAMS dwarfs. Comments by J.-C. Mermilliod and J. Stauffer on an early version of the manuscript are gratefully acknowledged. We also thank J. Stauffer for providing an updated database including the coordinates and dereddened optical properties of the stars studied here and J.-C. Mermilliod and S. Allain for letting us use rotational velocity measurements from the CORAVEL-ELODIE database prior to publication. We wish to thank the PUEO team at CFHT, especially J. Thomas, the MONICA team at Université de Montréal, in particular P. Vallée and R. Doyon, as well as K. Barton for their efficient support during the observations.

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