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New proper motions of pre-main sequence stars in Taurus-Auriga

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Abstract. We present proper motions of 72 T Tauri stars located in the central region of Taurus-Auriga (Tau-Aur). These proper motions are taken from a new proper motion catalogue called STARNET. Our sample comprises 17 classical T Tauri stars (CTTS) and 55 weak-line T Tauri stars (WTTS), most of the latter discovered by ROSAT. 53 stars had no proper motion measurement before.

Kinematically, 62 of these stars are members of the association. A velocity dispersion of less than 2-3 $\mathrm{km\,s^{-1}}$ is found which is dominated by the errors of the proper motions. This velocity dispersion correlates with a spread in distances.

Furthermore we present proper motions of 58 stars located in a region just south of the Taurus molecular clouds and compare the kinematics of the youngest stars in this sample (younger than $3.5 \cdot 10^7$ yrs) with the kinematics of the pre-main sequence stars (PMS) in the Taurus-Auriga association. From a comparison of the space velocities we find that the stars in the central region of Tau-Aur are kinematically different from the stars in the southern part.

Among the stars with large proper motions far off the Taurus mean motion we find 2 Pleiades candidates and 7 possible Pleiades runaway stars.

Key words: Stars: kinematics – Stars: formation – Stars: pre-main sequence – Stars: late-type – Astrometry

1. Introduction

The T-association Taurus-Auriga (Tau-Aur) is a large star forming region with several hundreds of pre-main sequence stars (PMS) known. Its distance of only about 140 pc (Elias 1978, Kenyon et al. 1994) makes it an ideal object for studying the properties of the cloud resulting from ongoing star formation, e.g. its stellar content, age, distribution and motion of the stars and so on.

Before the launch of ROSAT about 150 T Tauri stars which are associated with Taurus-Auriga have been known, most of them classical T Tauri stars (CTTS). The ROSAT All-Sky Survey (RASS) and some deep ROSAT pointings have revealed so far 4 new CTTS and 82 weak-line T Tauri stars (WTTS) in the central region of Taurus-Auriga, between 4^h and 5^h in right ascension and $+15^\circ$ and $+34^\circ$ in declination (Wichmann et al. 1996, Strom & Strom 1994, Carkner et al. 1996). Both CTTS and WTTS show the characteristic strong Li I λ 6708 Å absorption line, but in contrast to CTTS, WTTS are stronger X-ray-emitters (Neuhäuser et al. 1995a) and so easier to detect by ROSAT. WTTS however lack the strong Hα emission, Ca II emission and IR-excess of the CTTS, most of which were discovered by objective prism surveys.

In addition to these new TTS discovered in the central region of Taurus-Auriga pre-main sequence stars have also been found in a large area south of the Taurus-Auriga dark clouds (Neuhäuser et al. 1995b, Magazzù et al. 1997, Neuhäuser et al. 1997).

Proper motions of all these stars are required to kinematically investigate their membership to the association and to address the question whether it is possible that the stars outside the commonly adopted boundaries of Taurus-Auriga (based on CO surveys (Ungerechts & Thaddeus 1987)) have formed near the centre of the region or rather near their present locations. Until now proper motions have been known only for about 70 mostly classical T Tauri stars in selected areas inside the large region (Jones & Herbig 1979, Walter et al. 1987, Hartmann et al. 1991, Gomez et al. 1992).

2. Data

To cover the whole region a deep all-sky catalogue of proper motions is required. The proper motions we present in the following sections are taken from STARNET (Röser

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Table 1. STARNET proper motions for 34 stars which were known to be of PMS nature before ROSAT. In the second column references for previous measured proper motions are given: (1) Jones & Herbig 1979, (2) Walter et al. 1987, (3) Hartmann et al. 1991, (4) Gomez et al. 1992. The last column indicates whether it is a classical (c) or a weak-line (w) T Tauri star. Note that the values for SAO 76411 A are quoted from the PPM as there is no corresponding entry in STARNET. Remarks after the name of a star refer to stars not regarded as members of the Tau-Aur association and discussed separately in Sect. 4 ([(P)] Pleiades candidates, [(h)] other high proper motion stars).

object	ref.	GSC No./	PPM No.	RA (α_{2000})	DEC (δ_{2000})	m_V [mag]	μ_α [mas/y]	μ_δ [mas/y]	$\sigma\mu_\alpha \cos\delta$ [mas/y]	$\sigma\mu_\delta$ [mas/y]	TTS
NTTS 032641+2420 [(P)]		1802	1190	$3^h29^m38^s.39$	$+24°30'37''.6$	11.69	31	-43	3.4	3.4	w
NTTS 034903+2431 [(P)]		1804	123	3 52 2.26	+24 39 47.6	11.17	27	-51	4.8	4.8	w
SAO 76411 A [(P)]			93187	4 2 53.54	+22 08 11.7	9.30	43	-58	3.6	3.7	w
SAO 76428		1262	421	4 4 28.48	+21 56 4.0	9.33	4	-27	4.4	4.4	w
V773 Tau	(1)	1827	1236	4 14 12.94	+28 12 12.3	10.39	11	-21	4.9	5.0	c
FM Tau		1827	1032	4 14 13.59	+28 12 48.9	13.75	3	-39	5.9	5.9	c
CY Tau	(1)	1827	212	4 17 33.79	+28 20 46.8	12.98	17	-20	5.9	5.9	c
V410 Tau	(1)	1827	8	4 18 31.16	+28 27 15.9	10.37	17	-31	5.0	5.0	w
BP Tau	(1)	1827	554	4 19 15.85	+29 6 26.9	11.59	11	-29	3.9	3.9	c
RY Tau		1828	129	4 21 57.43	+28 26 35.4	10.09	16	-28	3.9	3.9	c
HDE 283572	(2)	1828	481	4 21 58.86	+28 18 6.3	8.70	11	-31	3.6	3.6	w
T Tau N	(1)	1272	470	4 21 59.40	+19 32 6.5	8.95	10	-13	4.4	4.4	c
DF Tau	(3)	1820	525	4 27 2.79	+25 42 23.1	11.82	0	-6	3.9	3.9	c
DG Tau	(3)	1820	330	4 27 4.70	+26 6 16.6	11.59	7	-10	3.7	3.7	c
NTTS 042417+1744	(4)	1269	913	4 27 10.57	+17 50 42.3	10.03	3	-17	3.3	3.3	w
UX Tau A	(4)	1269	225	4 30 3.90	+18 13 49.6	10.17	-2	-11	3.7	3.7	w
DK Tau	(3)	1833	37	4 30 44.27	+26 1 25.0	12.01	12	-14	5.0	5.0	c
L1551-51	(4)	1270	1195	4 32 9.30	+17 57 22.6	11.69	12	-20	4.3	4.3	w
V827 Tau		1270	1108	4 32 14.56	+18 20 14.8	12.00	10	-16	4.0	4.0	w
V826 Tau	(4)	1270	604	4 32 15.84	+18 1 38.7	11.81	11	-23	4.3	4.3	w
GG Tau		1270	897	4 32 30.32	+17 31 40.3	11.85	11	-28	3.9	3.9	c
V807 Tau		1829	214	4 33 6.62	+24 9 54.9	11.24	10	-21	3.7	3.7	c
V830 Tau	(3)	1833	843	4 33 9.99	+24 33 42.8	12.03	-14	-32	4.7	4.7	w
NTTS 043124+1824	(4)	1270	232	4 34 18.01	+18 30 6.6	12.70	-7	-8	3.9	3.9	w
NTTS 043220+1815		1270	1331	4 35 14.20	+18 21 35.5	10.85	-3	-15	3.3	3.3	w
DN Tau	(1)	1829	26	4 35 27.37	+24 14 58.8	12.17	3	-21	3.6	3.6	c
LkCa 14 [(h)]		1834	177	4 36 18.91	+25 43 1.4	11.61	-161	97	4.6	4.6	w
LkCa 15		1278	193	4 39 17.76	+22 21 3.7	11.65	0	-7	4.7	4.7	c
DS Tau		1843	937	4 47 48.42	+29 25 12.2	11.21	-18	-19	4.9	4.9	c
UY Aur	(1)	2387	982	4 51 47.38	+30 47 13.2	11.75	6	-26	5.1	5.1	c
LkCa 19		2387	637	4 55 36.97	+30 17 55.2	10.51	4	-18	4.2	4.2	w
SU Aur	(1)	2387	977	4 55 59.24	+30 34 1.5	8.37	-18	-28	4.2	4.2	c
NTTS 045251+3016		2387	535	4 56 2.04	+30 21 3.6	11.37	5	-25	4.2	4.2	w
RW Aur A	(1)	2389	955	5 7 49.50	+30 24 5.0	10.47	-11	-27	4.3	4.3	c

1996), which is a large proper motion catalogue well suited for our purposes. It contains about 4.3 million stars (most stars down to V=11.5 mag and some even fainter) with proper motions derived from plates with nearly 100 years epoch difference (Astrographic Catalogue (AC) and HST Guide Star Catalogue (GSC 1.2, Röser et al. 1996)). The average accuracy of the proper motions is about 5 mas/y, which corresponds to an error of about 3 km s^{-1} at the distance of Tau-Aur.

For brighter stars the PPM catalogue is a suitable source of proper motions. It contains some 400 000 stars down to about V=10.0 mag. On the northern hemisphere the measurements used in PPM have a smaller epoch difference than GSC and AC used for STARNET, but PPM contains more observations per star. In general, we took the proper motions from STARNET except in the following two cases: (1) There was no entry in STARNET, maybe because the star was too bright for the GSC or for

Table 2. All new ROSAT-discovered PMS stars (all WTTS) in the central region of Tau-Aur which we could identify in STARNET. The entries quoted for HD 283798 are from the PPM as the proper motions from PPM and STARNET deviate significantly for this star, probably due to a misidentification. Because BD +17 724 B is not present in STARNET we added its proper motion from the PPM. Remarks after the name of a star refer to stars with proper motions investigated in Table 4.

object	GSC No./ PPM No.		RA (α_{2000})	DEC (δ_{2000})	m_V [mag]	μ_α [mas/y]	μ_δ	$\frac{\sigma\mu_\alpha}{\cos\delta}$ [mas/y]	$\sigma\mu_\delta$
HD 285281	1258	894	$4^h\ 0^m 31\overset{s}{.}07$	$+19°35'20\overset{''}{.}6$	9.98	4	-16	3.9	3.9
RXJ 0403.4+1725 (h)	1254	309	4 3 24.85	+17 24 26.1	11.47	-66	-15	3.6	3.3
RXJ 0405.2+2632	1822	1383	4 5 12.33	+26 32 43.8	11.22	18	-22	4.0	4.0
RXJ 0405.3+2009	1258	338	4 5 19.60	+20 9 25.0	10.20	7	-22	3.6	3.6
HD 284135	1814	409	4 5 40.57	+22 48 11.7	9.26	2	-24	3.0	3.0
HD 284149	1258	257	4 6 38.81	+20 18 10.6	9.47	7	-22	2.9	2.9
RXJ 0406.8+2541	1818	144	4 6 51.34	+25 41 28.4	11.30	11	-21	4.2	4.2
RXJ 0407.9+1750 (P)	1254	785	4 7 53.99	+17 50 26.0	11.16	18	-49	3.9	3.9
RXJ 0409.2+2901 (P)	1826	877	4 9 9.81	+29 1 29.8	10.11	39	-37	3.5	3.5
RXJ 0412.8+2442	1819	498	4 12 51.22	+24 41 43.9	11.66	11	-19	5.7	5.7
HD 285579 (P)	1251	201	4 12 59.87	+16 11 47.6	10.74	13	-50	3.8	3.8
RXJ 0415.4+2044	1263	1027	4 15 22.95	+20 44 16.9	10.35	8	-17	4.6	4.6
RXJ 0420.4+3123	2371	740	4 20 24.13	+31 23 23.8	12.18	1	-15	7.9	7.9
BD +26 718	1824	592	4 24 48.18	+26 43 16.1	11.46	15	-20	5.0	5.0
BD +26 718 B	1824	183	4 24 49.09	+26 43 9.5	10.47	13	-27	5.0	5.0
BD +17 724 B	119907		4 27 5.97	+18 12 37.6	9.50	3	-7	3.8	3.8
RXJ 0430.8+2113	1277	574	4 30 49.15	+21 14 10.5	9.85	22	-26	4.4	4.4
HD 284496	1277	1238	4 31 16.85	+21 50 25.4	10.40	-5	-12	4.4	4.4
RXJ 0432.7+1853	1274	1501	4 32 42.43	+18 55 10.0	10.54	-3	-18	3.5	3.5
RXJ 0433.7+1823	1270	230	4 33 42.00	+18 24 27.4	11.93	-14	-9	3.3	3.3
RXJ 0437.5+1851 (P)	1274	1515	4 37 26.87	+18 51 25.2	10.73	16	-52	3.4	3.4
HD 285957	1266	1195	4 38 39.01	+15 46 12.9	9.86	-5	-33	5.2	5.2
RXJ 0439.4+3332A (P)	2378	1232	4 39 25.48	+33 32 44.8	11.17	30	-40	9.2	9.2
HD 283798	93702		4 41 55.16	+26 58 49.3	9.80	-3	-26	2.2	2.1
RXJ 0444.9+2717	1839	643	4 44 54.40	+27 17 45.6	9.00	-2	-18	5.1	5.1
HD 30171	1267	425	4 45 51.29	+15 55 49.2	8.95	10	-28	4.2	4.2
RXJ 0448.0+2755	1839	1278	4 48 0.41	+27 56 19.8	12.35	-10	-2	6.3	6.3
RXJ 0450.0+2230	1292	639	4 50 0.18	+22 29 57.7	11.07	-5	-14	3.3	3.3
RXJ 0452.8+1621	1280	559	4 52 50.14	+16 22 9.1	11.31	1	-23	4.8	4.8
RXJ 0453.0+1920	1288	790	4 52 57.06	+19 19 50.1	12.07	-3	-23	3.9	3.9
HD 31281	1284	1193	4 55 9.60	+18 26 30.6	9.12	-9	-28	3.8	3.8
RXJ 0455.8+1742	1284	522	4 55 47.64	+17 42 1.6	11.16	-12	-28	3.9	3.9
HD 286179	1281	1215	4 57 0.62	+15 17 52.6	10.06	-8	-24	5.1	5.1
RXJ 0457.1+3142	2388	857	4 57 6.52	+31 42 50.0	10.06	-2	-20	4.4	4.4
RXJ 0457.2+1524	1281	1288	4 57 17.64	+15 25 9.1	10.11	-1	-23	4.9	4.9
RXJ 0457.5+2014	1289	513	4 57 30.63	+20 14 28.5	10.89	-9	-34	3.6	3.6
RXJ 0458.7+2046	1293	2396	4 58 39.71	+20 46 43.1	11.65	-3	-38	5.7	5.7
RXJ 0459.8+1430	697	960	4 59 46.14	+14 30 55.1	11.81	3	-21	5.0	5.0

any other reason. In our sample this was only the case for SAO 76411 A, BD +17 724 B and BD +12 511. (2) The proper motions from STARNET and PPM deviated significantly from each other. This happened for the stars HD 283798 and BD +07 582(B), for which STARNET gives very high proper motions. We assume that this is due to a wrong identification of the star on the plates. This is a consequence of the very large epoch difference, which on the one hand reduces errors in the proper motions, but on the other hand makes the identification of high proper motion stars more difficult and sometimes erroneous. In these cases, PPM is the more reliable source, as it contains more observations per star. Stars with large proper motions are discussed in Sect. 4 in more detail.

Table 3. STARNET proper motions for stars not older than $3.5 \cdot 10^7$ yrs, 10^8 yrs old stars and stars older than 10^8 yrs in a region located somewhat south of the Taurus molecular clouds. The entries for the stars BD +07 582 and BD +07 582 B are from PPM as there is only one entry in STARNET for both components with a quite different proper motion. Remarks after a star's name refer again to stars discussed in Sect. 4.

object	GSC No./ PPM No.		RA (α_{2000})	DEC (δ_{2000})	m_V [mag]	μ_α [mas/y]	μ_δ	$\sigma\mu_\alpha \cos\delta$ [mas/y]	$\sigma\mu_\delta$
stars not older than $3.5 \cdot 10^7$ yrs									
RXJ 0324.4+0231	60	489	$3^h24^m25^s.25$	+2°31′ 1″.1	12.83	24	-3	4.3	4.3
RXJ 0338.3+1020	660	709	3 38 18.21	+10 20 16.7	10.97	19	-25	3.5	3.5
RXJ 0344.8+0359	68	1471	3 44 53.16	+ 3 59 30.4	12.26	17	-18	4.9	4.9
RXJ 0347.9+0616	71	542	3 47 56.82	+ 6 16 6.9	11.06	15	-5	3.5	3.5
RXJ 0348.5+0832	658	922	3 48 31.47	+ 8 31 37.7	10.90	33	-7	4.0	4.0
RXJ 0354.1+0528	72	606	3 54 6.57	+ 5 27 23.4	11.63	-9	-9	3.9	3.9
RXJ 0354.3+0535	72	921	3 54 21.27	+ 5 35 40.8	10.17	-9	-5	3.9	3.9
RXJ 0357.3+1258	665	150	3 57 21.37	+12 58 16.9	10.89	21	-18	5.2	5.2
BD +07 582 B (*)	147111		4 0 9.39	+8 18 18.9	10.80	-22	-15	9.3	9.3
RXJ 0407.2+0113 N	73	762	4 7 16.44	+ 1 13 14.4	11.14	18	-4	3.4	3.4
RXJ 0422.9+0141	75	41	4 22 54.61	+ 1 41 31.8	12.29	-11	-8	4.1	4.1
RXJ 0427.4+1039	672	1265	4 27 30.28	+10 38 48.6	11.33	-2	-9	4.1	4.1
RXJ 0427.5+0616	81	1414	4 27 32.07	+ 6 15 51.9	10.29	5	1	3.5	3.5
RXJ 0434.3+0226	86	318	4 34 19.50	+ 2 26 25.7	13.01	3	-25	4.6	4.6
BD +08 742	682	674	4 42 32.14	+ 9 6 1.4	10.86	36	-20	6.6	6.6
RXJ 0450.0+0151	84	743	4 50 4.69	+ 1 50 42.7	12.15	11	-12	4.1	4.1
RXJ 0511.9+1112	702	1689	5 12 0.29	+11 12 19.5	11.38	2	-5	3.6	3.6
RXJ 0512.0+1020	702	2533	5 12 3.19	+10 20 6.7	11.32	1	6	3.6	3.6
≈ 10^8 yrs old stars									
RXJ 0219.7-1026	5282	2210	$2^h19^m47^s.39$	-10°25′40″.7	11.60	15	-2	3.7	3.7
HD 15526 (h)	5284	686	2 29 35.07	-12 24 9.0	10.32	48	-13	3.8	3.8
RXJ 0329.1+0118	57	485	3 29 8.06	+ 1 18 5.5	10.90	4	-6	2.9	2.9
RXJ 0339.6+0624	70	1148	3 39 40.56	+ 6 24 43.5	11.70	-3	-6	5.5	5.5
RXJ 0343.6+1039	660	825	3 43 40.49	+10 39 13.7	10.21	-8	-32	3.8	3.8
BD +11 533 (*)	661	452	3 52 24.76	+12 22 43.2	9.65	5	-25	4.4	4.4
BD +07 582 (*)	147110		4 0 9.32	+8 18 13.7	10.70	-10	-36	4.6	4.6
RXJ 0404.4+0519	79	810	4 4 28.48	+ 5 18 43.0	11.18	10	-11	3.0	3.0
HD 286556	674	504	4 9 51.55	+12 9 1.9	12.02	4	-28	4.2	4.2
RXJ 0423.5+0955	672	1156	4 23 30.22	+ 9 54 29.3	11.64	-15	-14	5.3	5.3
HD 286753	676	1123	4 25 35.33	+12 9 59.4	10.40	30	-23	3.4	3.4
RXJ 0442.9+0400	91	702	4 42 54.72	+ 4 0 11.6	11.13	13	-17	3.6	3.6
stars older than 10^8 yrs									
RXJ 0210.4-1308 SW (h)	5283	1690	$2^h10^m25^s.82$	-13° 7′56″.6	10.48	55	-24	4.0	4.0
RXJ 0212.3-1330 (h)	5283	876	2 12 18.73	-13 30 42.4	11.41	163	-81	4.1	4.1
RXJ 0218.6-1004	5282	68	2 18 39.56	-10 4 6.0	11.75	18	-16	4.4	4.4
RXJ 0239.1-1028 (h)	5288	1027	2 39 8.77	-10 27 46.4	13.21	-8	-95	5.0	5.0
RXJ 0248.3-1117	5289	1010	2 48 22.21	-11 17 12.4	12.02	14	-10	3.8	3.8
RXJ 0309.1+0324	58	166	3 9 9.89	+ 3 23 44.0	10.39	31	-9	3.5	3.4
RXJ 0317.9+0231 (h)	59	24	3 17 59.16	+ 2 30 12.0	10.73	-15	-61	4.2	4.2
RXJ 0330.7+0306 N (h)	67	206	3 30 43.48	+ 3 5 46.9	11.18	33	-85	3.9	3.9
RXJ 0336.0+0846 (h)	657	726	3 36 0.28	+ 8 45 36.7	12.35	1	26	7.4	7.4
BD +12 511	119389		3 49 27.76	+12 54 43.8	9.60	-42	45	4.0	3.9

(*) classification is doubtful (Neuhäuser et al. 1997), these stars may either be ZAMS or PMS stars

Table 3. (continued)

object	GSC No./	PPM No.	RA (α_{2000})	DEC (δ_{2000})	m_V [mag]	μ_α [mas/y]	μ_δ	$\sigma\mu_\alpha \cos\delta$ [mas/y]	$\sigma\mu_\delta$
stars older than 10^8 yrs									
RXJ 0402.5+0552	79	729	$4^h\ 2^m 35^s.71$	$+5^\circ 51' 36''.5$	10.80	33	41	3.3	3.3
RXJ 0405.5+0324	76	713	4 5 30.24	+ 3 23 50.1	11.49	8	-5	4.4	4.4
RXJ 0418.6+0143	74	1029	4 18 39.24	+ 1 42 9.6	12.34	-14	-39	4.2	4.2
RXJ 0426.4+0957W	672	1133	4 26 26.79	+ 9 56 59.8	11.47	15	13	5.3	5.3
BD +00 760 (h)	75	1529	4 27 53.09	+ 0 49 25.6	9.60	57	-8	3.3	3.3
RXJ 0429.9+0155	75	1	4 29 56.87	+ 1 54 47.3	10.48	-3	-5	3.7	3.7
RXJ 0435.5+0455	90	936	4 35 31.55	+ 4 55 32.3	9.91	-12	5	3.0	3.0
BD +05 706	91	830	4 41 57.70	+ 5 36 34.5	9.62	5	-1	3.9	3.9
RXJ 0442.3+0118	83	788	4 42 18.59	+ 1 17 39.6	11.79	-3	-29	3.3	3.3
RXJ 0442.6+1018	686	1246	4 42 40.87	+10 17 44.3	8.25	33	-33	5.2	5.2
HD 287017 (P)	687	419	4 44 20.44	+ 9 41 3.3	8.86	52	-73	5.1	5.1
RXJ 0445.3+0914	683	282	4 45 23.81	+ 9 13 48.6	11.75	-1	-7	4.6	4.6
RXJ 0448.0+0738 (P)	683	661	4 48 0.89	+ 7 37 56.2	11.15	25	-59	4.2	4.2
RXJ 0515.3+1221	707	1311	5 15 20.57	+12 21 13.5	11.59	24	-31	4.5	4.5
RXJ 0523.5+1005	704	2521	5 23 33.72	+10 4 29.2	11.23	-4	-33	4.4	4.4
RXJ 0523.9+1101 (h)	704	2073	5 23 57.05	+11 0 55.7	10.83	2	-115	3.4	3.4
RXJ 0528.4+1213	708	2137	5 28 25.70	+12 12 36.1	11.50	-6	-2	4.4	4.4
RXJ 0530.9+1227	709	1637	5 30 57.20	+12 27 26.4	10.69	6	-24	5.4	5.4

The positions in all tables are valid for equinox and epoch J2000.0. Note that the mean errors in μ_α are multiplied by $\cos\delta$ (whereas the proper motions themselves are not).

2.1. Proper motions of PMS stars known prior to ROSAT

In STARNET or in the PPM we could identify 34 PMS stars known prior to the ROSAT mission. Their proper motions are given in Table 1. Of these, 15 stars had no proper motion measurement so far. Previous determinations of proper motions were performed in the surveys of Jones & Herbig (1979) (which was the most extensive one, including 80 suspected or confirmed T Tauri stars together with 241 stars possibly associated with Tau-Aur) and in the spatially more restricted surveys by Hartmann et al. (1991) and Gomez et al. (1992). These previous papers publish relative proper motions of stars on pairs of photographic plates. This is not an obstacle to local kinematics. However, it prevents us from a comparison of the individual accuracy in these previous papers and in the present one, because the number of stars in common is so small.

2.2. Proper motions of PMS stars discovered by ROSAT

2.2.1. The central region of Tau-Aur

ROSAT observations in a region including the centre of Tau-Aur in combination with optical follow-up spectroscopy have revealed 4 new classical and 72 new weak-line T Tauri stars (Wichmann et al. 1996). Of these, 38 stars (all WTTS) have proper motions either in STARNET or in the PPM which are given in Table 2. Additional pointed ROSAT observations led to the discovery of 8 confirmed (Strom & Strom 1994), 2 likely and 5 possible TTS (Carkner et al. 1996), but none of them could be found in STARNET because they are too faint.

2.2.2. Region south of Tau-Aur

Recently Neuhäuser et al. (1995b, 1997) and Magazzù et al. (1997) have studied a sample of 111 stars in a region located just south of the Taurus molecular clouds. The field boundaries were chosen by these authors in such a way that the Orion field (in the lower left in Fig. 1) was excluded. The strip in the lower right of Fig. 1, which is perpendicular to the galactic plane, was included in order to search for a gradient in the space density of TTS as a function of distance from the Taurus clouds.

Proper motions of 58 stars in the sample of these authors are available, 55 from STARNET, supplemented by

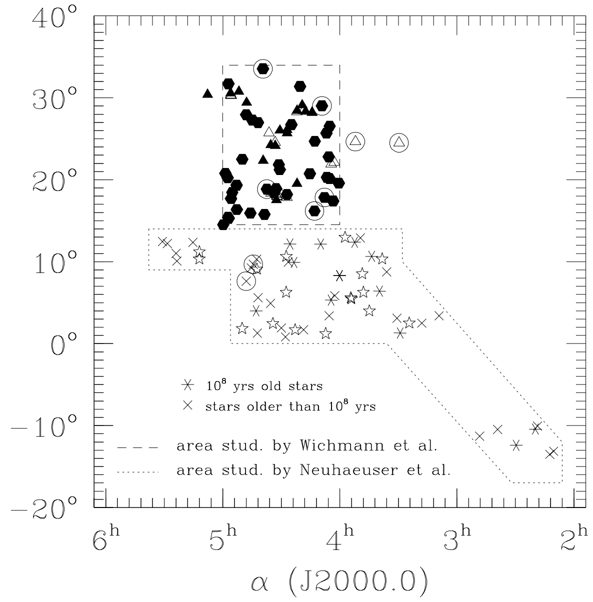

Fig. 1. Positions of the stars in Tables 1-3. Stars of Table 1 (TTS known prior to ROSAT) are marked with triangles (CTTS filled, WTTS open), stars of Table 2 (WTTS studied by Wichmann et al. 1996) with filled hexagons and the youngest stars of Table 3 (stars studied by Neuhäuser et al. 1995b, 1997 and Magazzù et al. 1997) with open stars. 10^8 yrs old stars and stars older than 10^8 yrs of Table 3 are marked with centered stars and crosses, respectively. A circle around a symbol indicates possible Pleiades members, see Sect. 4. The regions studied by those authors are indicated, too.

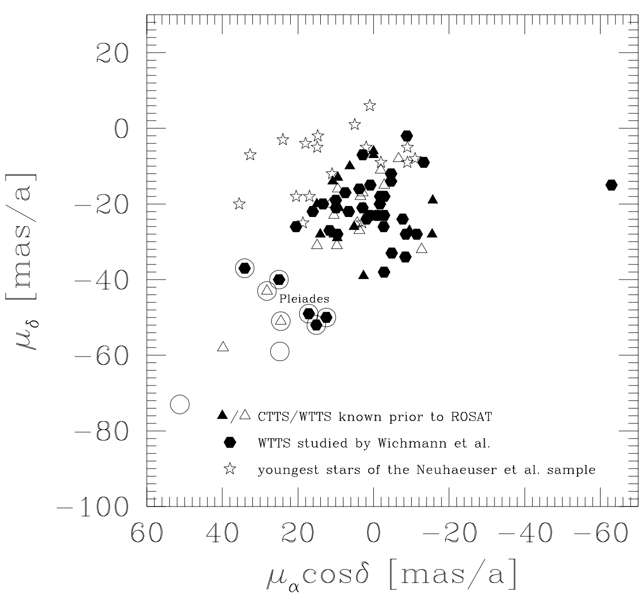

Fig. 2. Proper motions of all the stars in the centre (Tables 1 and 2) and of the youngest stars in the south (upper part of Table 3). The coding of the different stars is the same as in Fig. 1. Note that the proper motion of LkCa 14 is too large to be shown in this diagram (it maybe wrong anyway, see Sect. 4).

3 from PPM. The data are given in Table 3. Of these, 18 stars are classified as very young stars with ages $\leq 3.5 \cdot 10^7$ yrs (with lithium excess above Pleiades level), 12 as stars with ages around $\approx 10^8$ yrs (with lithium, but no excess) and 28 stars as even older with ages $> 10^8$ yrs (without any detected lithium) by Neuhäuser et al. (1997). The youngest stars with spectral types F or G are just reaching the main-sequence, whereas stars with spectral type K are pre-main sequence stars.

3. Kinematics

3.1. Velocity dispersion

Positions and proper motions of the stars from Tables 1-3 are shown in Figs. 1 and 2. We exclude stars with proper motions clearly off the Taurus mean motion from the discussion in this section; they are discussed separately in Sect. 4. Clustering of the remaining stars around the overall mean values $(\mu_\alpha \cos\delta, \mu_\delta) = (4.0, -18.7)$ mas/y is visible in the proper motion diagram, and we immediately note that there is a relatively large scatter around the mean motion. Also, there is a slight difference in motion between the stars in the central region (Tables 1 and 2) with a mean proper motion of $(2.4, -21.1)$ mas/y and those from the southern region (upper part of Table 3) with a mean of $(10.1, -9.8)$ mas/y. The difference in μ_α (μ_δ) is significant with confidence level larger than 95% (99.9%) in a t-test for distributions with different dispersions.

We first discuss the velocity dispersion inferred from the scatter in proper motions. The distance of the Tau-Aur clouds is determined to be 140 pc (Elias 1978, Kenyon et al. 1994). Recently Preibisch & Smith (1997) have determined a best fit distance of 152 ± 10 pc on the basis of rotational properties of 25 WTTS, in good agreement with previous determinations of the distance of the whole cloud. At a distance of 140 pc the scatter in proper motion corresponds to a velocity dispersion in one coordinate of 6.5 km s^{-1} for the whole complex. Splitting the sample into stars in the central and the southern region, we find a velocity dispersion in the central part of Tau-Aur of 5.4 km s^{-1}, while the stars in the southern region exhibit a velocity dispersion of 7.6 km s^{-1}.

The mean error of the STARNET proper motions of 5 mas/y (Röser 1996) corresponds to 3.3 km s^{-1} at a distance of 140 pc. Subtracting this from the observed scatter we get an intrinsic scatter of 4.3 km s^{-1} for the stars in the central part and 6.8 km s^{-1} for the stars in the southern region. These values appear very large compared to previous investigations. Jones & Herbig (1979) derive an overall intrinsic velocity dispersion of 3.2 km s^{-1} and 2.2 km s^{-1} in their x- and y-direction (x essentially parallel to right ascension, y parallel to declination), respectively, but the

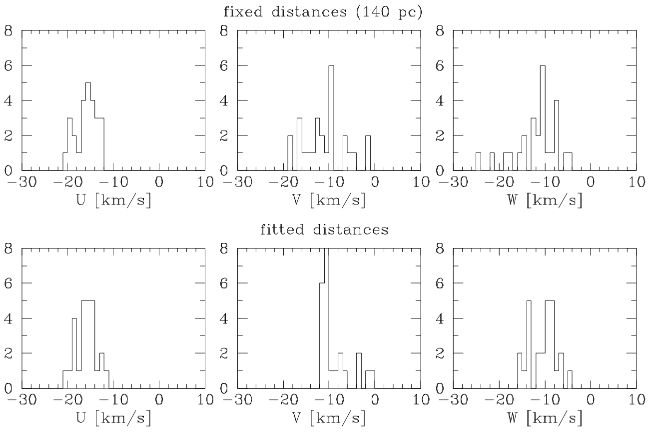

Fig. 3. Space velocities for 26 TTS of Table 1 with radial velocities available. In the upper panel space velocities are calculated assuming fixed distances of 140 pc for all stars, in the lower panel distances are adjusted so that the resulting space velocity for every star is as close as possible to the mean space velocity of the upper panel. U points in the direction of the galactic centre, V in the direction of galactic rotation and W towards the north galactic pole. The highest peak in the V velocities based on fitted distances is due to 11 stars.

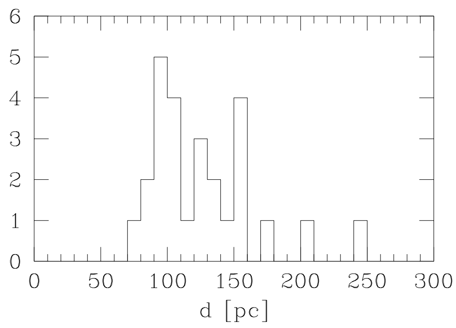

Fig. 4. Distance histogram for the stars shown in Fig. 3. Distances are calculated requiring that the resulting space velocities are close to the mean. The mean of the distances is 127 pc with a dispersion of 39 pc.

region investigated by Jones & Herbig (1979) is smaller than our 'central region' which is roughly the same as in Wichmann et al. (1996).

There is a significant difference in the determination of proper motions in Jones & Herbig (1979) and proper motions from STARNET. The region in Jones & Herbig (1979) is separated into subregions each corresponding to plate pairs. Proper motions are determined differentially from these plate pairs. This minimizes the effect of projection of the space motions over large areas of the sky, which is inherent in our proper motions because they are absolute proper motions (on the system of FK5).

The mean proper motion of $\mu_x = 6.4$ mas/y and $\mu_y = -22.0$ mas/y given by Jones & Herbig (1979) is comparable to our mean motion, indicating that the difference of the two astrometric systems is small. A thorough conversion of the proper motions between the Jones-Herbig system of relative proper motions and the FK5 system of STARNET proper motions is not possible because only few stars are in common.

Jones & Herbig (1979) subdivided the complex into smaller subregions, as they had a fainter limiting magnitude and a larger number of stars. Within these subgroups they determine the intrinsic velocity dispersion in the following way. From the measured scatter of the proper motions they subtract the scatter expected from the accuracy of their measurements. However, these two quantities are almost equal. So, they derive an upper limit of 1-2 $\mathrm{km\,s^{-1}}$ in most of their subgroups. The size of our sample does not allow for a further subdivision. We can only study the velocity dispersion of the complex as a whole. A velocity dispersion of 5.4 $\mathrm{km\,s^{-1}}$ would disintegrate the Tau-Aur complex in a time of the order 10^7 years, but typically smaller than the ages of the PMS stars. We suppose that a large part of the measured velocity dispersion can be attributed to the ad hoc assumption that all stars are situated at a distance of 140 pc, and we discuss this in the next section.

3.2. Space velocities

As the stars of our sample populate a large region on the sky the influence on proper motions caused by projection effects has to be taken into account. It is necessary to consider the total space velocities for a discussion of the velocity dispersion. In the literature (see Table 1 in Neuhäuser et al. 1995a for references) we found radial velocity measurements for 28 stars in the central area of Table 1.

Space velocities of 26 of these stars (omitting the 2 stars with zero proper motion components) calculated under the assumption of a fixed distance of 140 pc for all stars are shown in Fig. 3 (upper panel). The corresponding velocity dispersions are $\sigma_U = 2.4\,\mathrm{km\,s^{-1}}$, $\sigma_V = 4.8\,\mathrm{km\,s^{-1}}$ and $\sigma_W = 4.7\,\mathrm{km\,s^{-1}}$. The low dispersion in U is caused mainly by the distance-independent radial velocities. The large dispersion in V and W cannot be explained by the mean errors of STARNET proper motions, and we suggest that it is (at least partly) due to the lack of knowledge of the true distances.

We tested this hypothesis by varying the distance of each star in order to minimize the difference between the corresponding space velocity and the mean space velocity of the complex at a fixed distance of 140 pc. By this, the dispersion in the velocity components is significantly reduced to 2.1 $\mathrm{km\,s^{-1}}$, 3.3 $\mathrm{km\,s^{-1}}$ and 2.8 $\mathrm{km\,s^{-1}}$ (Fig. 3; lower panel). The resulting velocity dispersion is now almost equal in all three components, an indication for the correctness of our hypothesis. A velocity dispersion of about 3 $\mathrm{km\,s^{-1}}$ in one component is very close to the

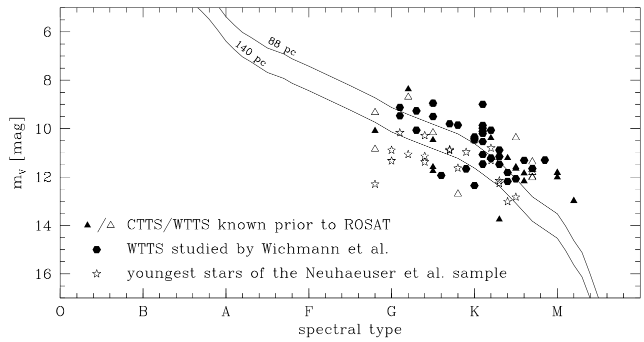

Fig. 5. Hertzsprung Russell diagram for the stars of Tables 1 and 2 and the youngest stars of Table 3 without the high proper motion stars discussed separately in section 4. Apparent V-magnitudes are taken from GSC (typical errors 0.3 mag) without corrections for extinction. Spectral types are taken from SIMBAD for stars of Table 1, from Wichmann et al. (1996) for stars of Table 2 and from Magazzù et al. (1997) for the stars of Table 3. The ZAMS is calculated for a distances of 140 pc and 88 pc, respectively. Some pre-ROSAT CTTS and WTTS appear below the ZAMS because we did not correct for absorption.

formal error of STARNET proper motions. This sets an upper limit to the intrinsic velocity dispersion. This upper limit must be small compared to $3\,\mathrm{km\,s^{-1}}$ in order to have no influence on the measured velocity dispersion. This result is consistent with the result of Jones & Herbig (1979) for the smaller subgroups within their sample.

The distances calculated in the manner described above are shown in Fig. 4. The mean of these distances is 127 pc, close to 140 pc. Furthermore our sample is biased towards brighter stars, i. e. nearer and/or earlier type stars, so a slightly lower value than the distance to the whole cloud complex is expected for these stars. The dispersion of the distances is 39 pc which is comparable to the extent of the association in the tangential plane of at least 20° or 49 pc at a distance of 140 pc.

It is impossible to solve for the mean motion of the cluster and the distances of the stars simultaneously. Minimizing the velocity dispersion always favours lower distances and a lower mean cluster motion, so all these values would tend to zero. Minimizing only the relative dispersion, normalized to the absolute value of the space velocity, yielded a velocity dispersion which was much lower than expected from the errors of the STARNET proper motions and in turn an unbelievably high dispersion in the resulting distances.

These kinematically determined *individual* distances of the stars are not to be taken too literally; for this the method is too coarse. However, the method yields a general tendency for the distribution of the radial distances of the TTS in Taurus-Auriga.

3.3. Relation of the southern stars to Taurus-Auriga

We discuss different scenarios for the origin of the youngest stars in the southern region and their possible relation to the Taurus molecular clouds.

(a) First we assume that the young stars in the southern region belong to the Taurus-Auriga complex and share the same mean space motion. Because of their different proper motions the southern stars cannot fulfill the requirement of the same space motion if they are at a distance of 140 pc. Varying their distances as described above (with a solution in the distance interval between 50 pc and 300 pc for only 11 out of 16 stars), we find that they would be located at lower distances than the stars in the central area with a mean distance of 88 pc. This however leads to a conflict in the HR diagram (Fig. 5): Nearly all the stars in the south would lie below the main sequence for 88 pc which is in contradiction to their zero-age main sequence or even pre-main sequence nature. The velocity dispersions calculated with these distances are $\sigma_U = 4.7\,\mathrm{km\,s^{-1}}$, $\sigma_V = 2.6\,\mathrm{km\,s^{-1}}$ and $\sigma_W = 3.7\,\mathrm{km\,s^{-1}}$. The dispersions in V and W are close to the values derived for the stars in the central region, but the dispersion in U (which is more or less independent of the distances) is higher than expected for members of a common star forming region.

(b) If we assume that the stars are located at comparable distances to the Taurus-Auriga association of about 140 pc, this would make their location in the HR diagram comparable to the Taurus member stars. Kinematically they would not be related to the Taurus clouds, but the two complexes would rather approach each other with a relative velocity of $\approx 9\,\mathrm{km\,s^{-1}}$ and were adjacent to each other now only by chance. It might be possible that the Taurus clouds originated in a high-velocity cloud impact, so that the Taurus clouds oscillate around the galactic plane. During the last passage through the plane, the stars were separated (combing-out) from the Taurus clouds, and now move ahead and already begin to fall back to the plane. Alternatively, all the young stars south of Taurus may just be Gould's belt members with typical ages of $3\text{-}5{\cdot}10^7$ yrs; see Neuhäuser et al. (1997) for a discussion.

(c) If the stars were more distant than 140 pc the HR diagram would constrain them to be really very young pre-main sequence stars. At the same time they would show a velcocity dispersion higher than expected for a group of very young stars, and likewise very high X-ray luminosities. In the tangential plane the two complexes would pass more or less closely depending on the distance difference.

Neither of the above scenarios is completely convincing. Maybe the stars in the southern area do not have a common origin and are not located at approximately similar distances. Briceño et al. (1997) suggest that the population discoverd by ROSAT south of the Taurus clouds is not made up of pre-main sequence but rather main-sequence stars for which we do not expect that they share a common kinematic behaviour. On the other hand only a small fraction of the youngest stars in Table 3 are really PMS stars; about half of the PMS stars in Neuhäuser et al. (1997) are too faint for STARNET. None of the younger stars appear to be ejected from the northern Tau-Aur region. It should be kept in mind, however, that dynamically ejection mechanisms favour low-mass escapers (Sterzik & Durisen 1995). These stars are absent in this magnitude limited subsample.

Our kinematical findings indicate most probable that the PMS stars in the southern extension move towards the central Tau-Aur region. This implies a larger separation of the two complexes in the past. From the kinematical point of view a common star formation process seems therefore excluded. The larger ages of the southern stars support our conclusion that star formation in the two complexes must have been triggered by different events.

4. High proper motion stars in STARNET

4.1. Verification of high proper motions

Prior to the physical interpretation of the large proper motions of a number of stars, these proper motions have to be carefully investigated. As mentioned, STARNET proper motions are derived from AC and GSC. For a certain number of stars in STARNET misidentifications of their positions on the AC and/or GSC plates can occur because of the large ($\approx$ 80 years) epoch difference. We decided to cross-check large proper motions either by comparison with the proper motion given in another catalogue, if available, or by testing the star's position on the plates of a third epoch. This is by no means an easy task, because accurate astrometric data in this magnitude range are rare.

Table 4 summarizes the stars with large proper motions from Tables 1, 2 and 3. The sample can be split into stars with proper motions close to the mean proper motion of the Pleiades cluster ($\mu_\alpha \approx 16$ mas/y, $\mu_\delta \approx -44$ mas/y) and those with proper motions randomly far off the mean motion of Tau-Aur. The proper motions of 15 stars in Table 4 could be confirmed by comparison with their positions on the digitized POSS I plates or by independent proper motion measurements. This is indicated by a ✓-sign. The digitized POSS I is well suited to check the erroneously large proper motions because in this case there should be a large, easily detectable offset from the expected position. This turned out to be the case for the 6 remaining stars; their proper motions seem to be erroneous in STARNET

Table 4. Stars with conspicuous proper motions in our investigation. The last column indicates the result of the proper motion check via POSS I: a ✓-sign indicates that the proper motion could be confirmed, a ?-sign indicates a doubtful proper motion.

object	Tab.	GSC No. /	PPM No.	μ_α [mas/y]	μ_δ [mas/y]	
Pleiades candidates						
NTTS 032641+2420	1	1802	1190	31	-43	✓
NTTS 034903+2431	1	1804	123	27	-51	✓ (1)
SAO 76411 A (*)	1	93187		43	-58	✓ (2)
RXJ 0407.9+1750	2	1254	785	18	-49	✓
RXJ 0409.2+2901	2	1826	877	39	-37	✓
HD 285579	2	1251	201	13	-50	✓
RXJ 0437.5+1851	2	1274	1515	16	-52	✓
RXJ 0439.4+3332A	2	2378	1232	30	-40	✓
RXJ 0448.0+0738	3	683	661	25	-59	?
HD 287017	3	687	419	52	-73	✓ (2)
other high proper motion stars						
RXJ 0210.4-1308 SW	3	5283	1690	55	-24	✓
RXJ 0212.3-1330	3	5283	876	163	-81	✓ (2)
HD 15526	3	5284	686	48	-13	✓
RXJ 0239.1-1028	3	5288	1027	-8	-95	✓
RXJ 0317.9+0231	3	59	24	-15	-61	?
RXJ 0330.7+0306 N	3	67	206	33	-85	?
RXJ 0336.0+0846	3	657	726	1	26	✓
RXJ 0403.4+1725	2	1254	309	-66	-15	?
BD +00 760	3	75	1529	57	-8	✓ (2)
LkCa 14	1	1834	177	-161	97	?
RXJ 0523.9+1101	3	704	2073	2	-115	?

(*) classified as non-member by van Leeuwen et al. (1986)
(1) checked by comparision with Schilbach et al. (1995)
(2) proper motion from PPM / checked in PPM

4.2. Pleiades membership

In the proper motion plot (Fig. 2) we find a secondary crowding of stars with proper motions similar to that of the Pleiades. Indeed the star NTTS 034903+2431 is found to match both photometric and proper motion membership criteria of the Pleiades cluster by Schilbach et al. (1995, their star No. 36000) and classified as highly probable Pleiades member. SAO 76411 A, on the other hand, corresponds to the star Pels 178, which was included in the photometric investigation of the Pleiades cluster by van Leeuwen et al. (1986) and classified as non-member.

Figure 6 shows the distribution on the sky of the stars from the upper part of Table 4 with the exception of SAO 76411 A. The direction to the centre of the Pleiades cluster is indicated by a filled circle. The arrows show the proper motions of the stars from Table 4 relative to the mean motion of the Pleiades in PPM and STARNET. Two stars close to the centre of the Pleiades have small motions relative to the Pleiades cluster; one of them is the star classified as highly probable proper motion member by

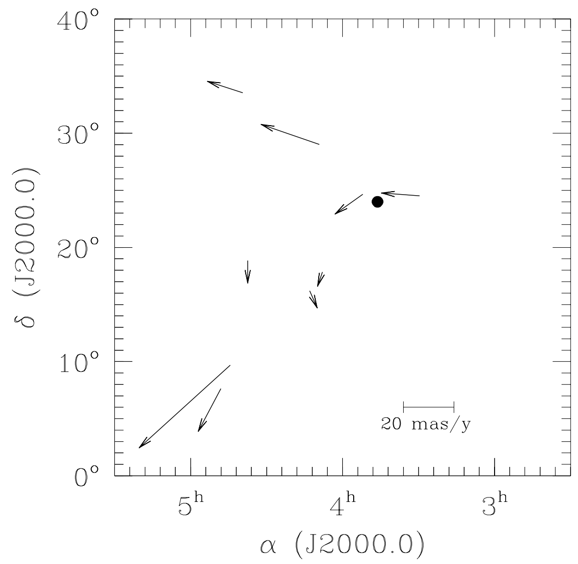

Fig. 6. Position of the Pleiades member stars and direction of their proper motions relative to the cluster mean ($\mu_\alpha = 16\,\mathrm{mas/y}$, $\mu_\delta = -44\,\mathrm{mas/y}$). The filled circle indicates the centre of the Pleiades cluster at about $\alpha = 3\overset{h}{.}8$, $\delta = 24\overset{\circ}{.}0$. The scale for the length of the arrows is indicated in the lower right corner of the plot.

Schilbach et al. (1995). Three stars about 10° away from the Pleiades centre show no relative motion and should be checked further photometrically for membership. Finally, the stars RXJ 0409.2+2901, RXJ 0439.4+3332A, RXJ 0448.0+0738 and HD 287017 could have been ejected from the Pleiades a few million years ago. This is consistent with the findings of Kroupa (1995), who expects from the result of numerical N-body simulations of star clusters that during the lifetime of a cluster a certain fraction of stars can be ejected with velocites up to 100 km/s due to close encounters between binary systems. The ejection rate is estimated to be higher in the earlier phases of cluster evolution.

5. Summary and conclusion

We have presented new proper motions taken from the STARNET catalogue of 62 stars in the central region of Taurus-Auriga whose kinematics is consistent with membership to the association. These stars show a velocity dispersion small compared to $3\,\mathrm{km\,s^{-1}}$, a limit which is given by the accuracy of the STARNET proper motions. This is consistent with the derivation of an upper limit for the velocity dispersion in subgroups of the Taurus-Auriga complex of about 1-2 $\mathrm{km\,s^{-1}}$ by Jones & Herbig (1979).

Among the high proper motion stars in our sample we found 8 new Pleiades candidates or runaways (and re-identified 1 known before). They are located up to $\approx 20°$ away from the centre of the Pleiades cluster, and their directions of motion are consistent with them being ejected from the cluster a few million years ago.

Finally, all attempts to kinematically relate the recently detected PMS stars south of the Taurus-Auriga cloud to the central part of this association have failed. We do not find any young stars in our sample that appear to be ejected from the Taurus-Auriga association. We conclude from this that the star formation scenario - at least for the G and early K type stars - in this southern area is different from the one in the central part.

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