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Hipparcos distances of X-ray selected stars: implications on their nature as stellar population *

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Abstract. We present the parallaxes, measured by Hipparcos, for a sample of X-ray selected stars. The stars belong to the stellar sample of the *Einstein Extended Medium Sensitivity Survey.* They are all at galactic latitude $|b| > 20\,\mathrm{deg}$, and are generally far away from known star forming regions. Several of these stars show lithium abundance and activity level typical of very young stars with ages comparable to that of the Pleiades. We show that the majority of our sample stars are on the main sequence, with only $\approx 20\%$ being giants. We do not find a significant presence of pre-main sequence stars in our sample, notwithstanding the fact that some of our stars have a considerable lithium abundance, showing that the stars observed are most likely young and active main-sequence objects.

Key words: Astrometry – Stars: activity – Stars: late-type

1. Introduction

Analysis of the stellar samples detected in X-ray flux limited surveys has lead to the identification of a population of late-type active stars, which, due to their unremarkable optical characteristics, would have been very difficult to identify otherwise. Since the first results based on *Einstein* observations, X-ray surveys have been a powerful mean to select young active stars which would otherwise be hardly distinguishable from "normal" stars (except through high-resolution optical spectroscopy). Such young and active late-type stars have been found both near star forming regions (SFR, Feigelson et al. 1987, Walter et al. 1988), and more generally spread around the sky, at high Galactic latitude, through the analysis of the stellar content of the *Medium Sensitivity Survey* (MSS, Maccacaro et al. 1982) and of the *Extended Medium Sensitivity Survey* (EMSS) (Gioia et al. 1990, Favata et al. 1988, 1993, Sciortino et al. 1995). Young, X-ray selected stars, detected near known SFR in *Einstein*-based surveys, have mostly been classified as "Weak-line T Tauri Stars" (WTTS), i.e. stars yet in a pre-main sequence (PMS) phase, but with optical characteristics less extreme than those of the classical T Tauri (CTTS). In particular, WTTS show Hα fill-in or (moderate) emission, and strong lithium absorption typical of young or PMS stars. X-ray selected stars detected in the high latitude surveys from *Einstein*, away from known SFR, have mostly been classified as young stars already on the main sequence with age of the same order of that of the Pleiades, although their precise evolutionary state has been difficult to assess due to the lack of reliable information on their distance. Similar conclusions have been reached from the analysis of the stellar content of the High Latitude X-ray EXOSAT survey (Tagliaferri et al. 1994) and of the ROSAT WFC Bright Source Catalog (Pounds et al. 1993, Jeffries & Bromage 1993, Hodgkin & Pye 1994). It is still unclear if the two stellar populations (i.e. the one classified as WTTS and the one classified as young main-sequence) are really two different classes of stars or not and, if they are different, in which proportion are they mixed together.

Recently, the analysis of the stellar counterparts of X-ray sources detected with the *ROSAT All Sky Survey* (RASS, Alcalá 1995, 1996a, 1996b, Krautter et al. 1996, Neuhäuser et al. 1995, Sterzik et al. 1995, Wichmann et al. 1996, 1997) around some known SFR's has shown the existence of a large number of young stars in the sky around the SFR itself. These young stars have been detected in extended areas of the sky, implying their being at distances from the supposed parent SFR much larger than what has, up to now, been considered plausible given what it

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is known on the star forming process (Feigelson 1996 and reference therein). These stars are currently considered WTTS's ejected from the parent SFR, and their presence at large distances from the putative parent SFR, poses serious challenges to our current understanding of the processes involved in stellar formation (Feigelson 1996, Ghorti & Bhatt 1996, Neuhäuser et al. 1995, Sterzik et al. 1995).

More recently Briceño et al. (1997) have cast some doubts on the nature of these RASS-detected young stars, suggesting that they are likely to be main sequence stars younger than the Hyades. This is in agreement with Micela et al. (1993), who predicted, on the basis of a X-ray stellar counts model, which also incorporates the evolution of X-ray luminosity with stellar age during the main sequence phase (Favata et al. 1992), that at typical RASS limiting fluxes, a large number of young Pleiades- and Hyades-like stars would be detected.

The main problem in assessing the nature of the X-ray selected stars is that the WTTS have characteristics, both in X-ray and in optical, very similar to those of the young main sequence stars and is very difficult to find a diagnostic which can reliably separate the two populations. The most important difference between the two populations is their position on the HR diagram, which allows to immediately assess their evolutionary status.

Note that in the case of RASS-selected stars found around known SFR's mentioned above, all the detected stars have been *assumed* to be at the distance of the nearby SFR. Obviously, if the stars are main sequence objects, and they are at a smaller distance than the SFR, this simplistic assumption will erroneously make them fall in the region populated by PMS stars of the HR diagram, misinterpreting their nature. Thus, accurate distance measurements are the key to assess the evolutionary status of these X-ray selected stars.

In this paper we present the distances and other derived stellar parameters obtained by Hipparcos for the subsample of EMSS stars which were included in the Hipparcos Input Catalogue, with the aim of better understanding the nature of X-ray selected stellar populations of late-type stars.

In §2 we present the data and the subsample composition discussing its selection biases, in §3 we present the results, which will be discussed in §4.

2. The sample and the data

The sample discussed in the present paper is the subsample of the EMSS stellar sample included in the Hipparcos Input Catalogue (HIC, Turon et al. 1992). The input catalog has been frozen in 1989 (Turon 1989) on the basis of a number of scientific proposals which were received in 1982, and at the end was expanded to include "a substantial sampling of the most important stellar categories present in the solar neighborhood" (Turon et al. 1992). The magnitude limit at which the HIC is complete varies from $V = 7.3$ to $V = 9.0$ (depending on the region of the sky and on spectral type), and the catalog contains no stars fainter than $V = 13$. The sample discussed here has been defined in 1992, in the context of an accepted proposal to early access to the Hipparcos data of a large sample of active stars. For this reason the final composition of the selected sub-sample reflects the composition of the HIC (which was already frozen at the time of our proposal).

To define our sample we cross-correlated the positions of all the EMSS sources with those of the HIC stars, using a match radius of 2 arcmin, to take into account the IPC positional error. This process yielded a total of 84 EMSS stars which have been observed by Hipparcos.

The data products which have recently been delivered to the successful Hipparcos Principal Investigators (and which will be released to the community in 1997, in the form of the Hipparcos Catalogue, ESA 1997a, and of the Tycho Catalogue, ESA 1997b) contain several important quantities. In particular, they contain, for each individual star observed, accurate positions, parallaxes and proper motions, each with the standard error (or full covariance matrix). The catalog also contains accurate photometry for each stellar source, both in a broad bandpass (the Hipparcos bandpass) and in band-passes similar to the Johnson B and V bands (the B_T and V_T magnitudes from the Tycho experiment), also with the standard errors. In addition, a "best available" measurement of the magnitude in the Johnson V band is given in the Hipparcos Catalogue. This V magnitude is derived from Hipparcos or Tycho measurements or from ground-based measurements, depending on which is the most accurate. The same considerations apply to the $B - V$ color measurement provided in the Hipparcos Catalogue, derived either from Hipparcos and Tycho measurements or from available ground-based observations, whichever was more accurate. In the present paper we will only use the parallax, V and $B - V$ measurements from the Hipparcos Catalogue. For our sample, about two thirds of the V magnitude measurements derived from the Hipparcos Catalogue come (according to the relevant flag in the catalog) from Hipparcos measurements, the rest from ground-based measurements. The Hipparcos Catalogue also provides a variability flag related to the V magnitude. For the purpose of the present paper small levels of variability are not important. Only one of our sample stars shows macroscopic variability (> 0.6 mag), namely MS1110.7−2611, an early-type star.

Given the criteria with which the HIC has been originally assembled, we expect to preferentially select the optically brighter EMSS stars (which have a magnitude distribution extending to fainter magnitudes, see Fig. 1b). Given the X-ray flux limited nature of the EMSS, this is tantamount to selecting the stars with the smallest f_x/f_v, i.e. the less "extreme" among the X-ray active stars. In Fig. 1 we compare the apparent magnitude distribution of the selected sample with that of the sample studied by Fleming et al. (1989), which consists of the northern stellar content of the EMSS, while in Fig. 2 we compare the distributions in f_x/f_v for the same two groups.

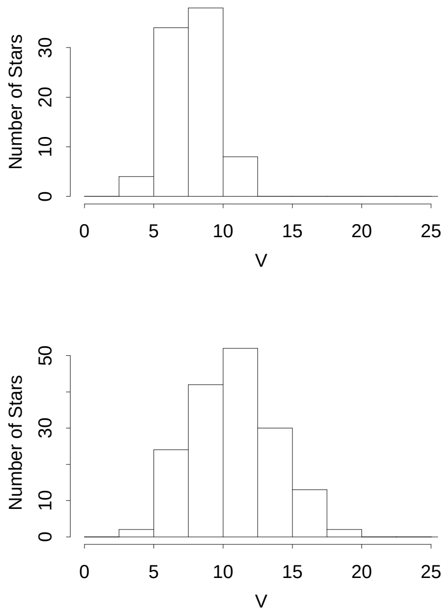

Fig. 1. The magnitude distribution of stars in our sample (upper panel) compared with the magnitude distributions of stars of the EMSS sample studied by Fleming et al. (1989, lower panel).

As expected, the HIC magnitude cut tends to select the (optically) brighter and less active (as measured by the f_x/f_v indicator) stars of the EMSS sample. This bias has the effect of removing the fainter and redder stars from the EMSS sample, which typically tend to be the most active ones, i.e. the ones with the highest f_x/f_v values. While there is certainly great interest in determining the evolutionary status of the fainter and most active stars in the EMSS sample, the subsample of the EMSS discussed here has a specific interest: the main peculiarity of the stellar content of the MSS and of the EMSS is the presence of an excess of yellow stars (Favata et al. 1988, Sciortino et al. 1995) with respect to what can be expected on the basis of the X-ray luminosity of "normal" stars. This excess is mainly concentrated in the magnitude range $7 \lesssim V \lesssim 12$ and in the activity range $-4 \lesssim \log(f_x/f_v) \lesssim -2$. In the present context the excess is defined with respect to the predictions obtained with a model of the X-ray stellar content of Galaxy (Favata et al. 1992, Micela et al. 1993, Sciortino et al. 1995) based on a model of our Galaxy (Bahcall & Soneira 1980) which has been modified to take into account the evolution of coronal activity during the main-sequence life and on the X-ray emission of nearby stars. Since the original discussion of this excess a number of photometric (Morale et al. 1996) and high resolution spectroscopic (Favata et al. 1993, 1995a) studies have been done aiming to determine the nature of the observed excess of X-ray selected stars. These studies excluded some of the hypotheses originally made about the nature of the excess objects, such as that they would be dominated by active binaries of the RS CVn-type, and showed that the excess population is a young one. However, lacking reliable distance determinations, these studies were not able (except for a few individual stars) to resolve whether the detected sources are young MS or PMS stars.

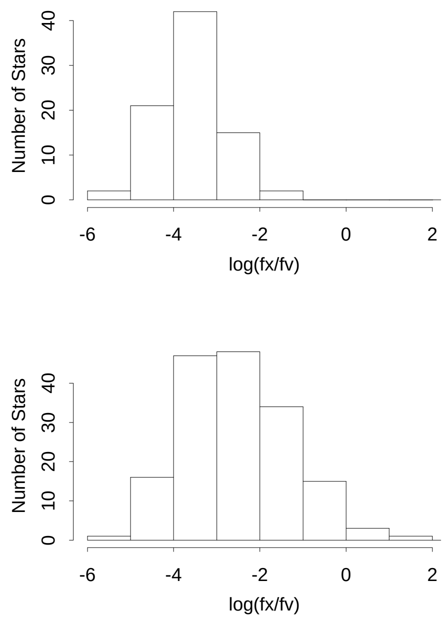

Fig. 2. The f_x/f_v distribution of stars in our sample (upper panel) compared with the f_x/f_v distribution of stars of the Fleming et al. (1989) sample (lower panel).

The ranges of apparent magnitude and of f_x/f_v where the excess population is concentrated correspond to those of the present sample for which the Hipparcos data are available, hence we are confident that the sample presented in this paper explores well the properties of the active stars responsible for the observed excess in the EMSS, and thus will help to determine its nature.

3. Results

As discussed above, the data obtained by Hipparcos include parallax measurements with their associated standard errors. In the following analysis only the stars having relative uncertainties on the parallax of less than 50% have been included. This restriction excludes only 2 objects from the sample. The distance distribution of the sample is shown in Fig. 3. Note that half of the stars have distances less than 50 pc, and 75% less than 100 pc.

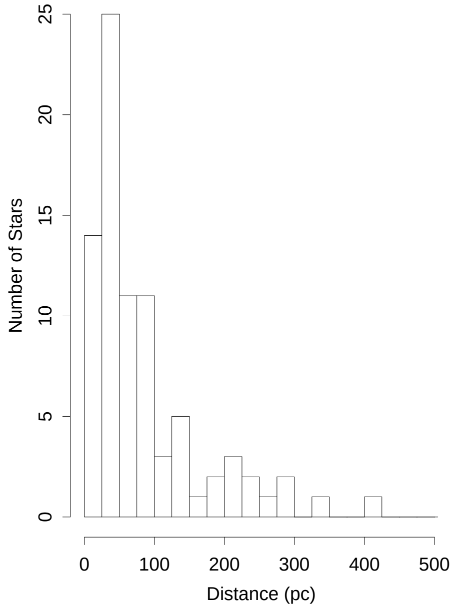

Fig. 3. The distance distribution of stars in our sample obtained using the Hipparcos parallaxes. Note the peak of stars with distance less than 50 pc.

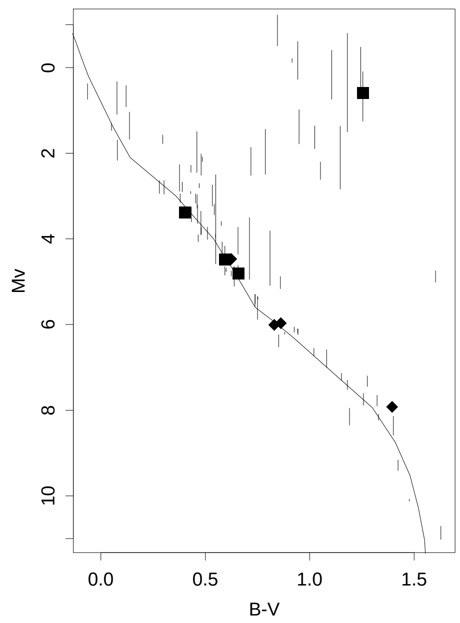

Fig. 4. HR diagram for the EMSS stars observed by Hipparcos. Vertical lines are the errors in the absolute magnitude due to the errors in Hipparcos distances. The continuous line is the main sequence (Keenan 1963, Johnson 1965) and filled squares represent high lithium stars from EMSS, while filled diamonds are the high lithium stars from SLEW survey (see text).

Starting from the Hipparcos parallax and from the V magnitude reported in the Hipparcos Catalogue (see § 2 about the source of the V magnitude in the Hipparcos Catalogue) we have computed, for each star in the sample, the distance, the absolute magnitude, the X-ray luminosity and the $\log(f_x/f_v)$ activity indicator (defined as $\log(f_x/f_v) = \log(f_x) + (V + 13.74)/2.5$). All the quantities for the sample stars are reported in Table 1, together with the lithium abundance for each source as reported by Favata et al. (1993, 1995a).

The absolute magnitude and the $B-V$ color have been used to compute the HR diagram for our sample stars, which is shown in Fig. 4. The extent of the vertical lines represents the uncertainty on the absolute magnitude due to the uncertainty on the parallax. The filled symbols are stars with an equivalent width of the Li I doublet larger than 100 mÅ, and will be discussed in detail later.

Inspection of Fig. 4 shows that the majority of the stars in our sample are main sequence objects, with a fraction (about 20%) lying on the giant branch. This circumstance makes us sure of the accuracy of the distances and associated errors measured by Hipparcos. The four solar type stars lying slightly above the main sequence are 1) HIP 14157, 2) HIP 56139, 3) HIP 59683, and 4) HIP 114000. The star 1) has a double spectrum, and the two companions are of similar spectral type (Favata et al. 1993), the observed displacement from the main sequence is that expected for such a binary system. The star 2) is a typical RS CVn (Favata et al. 1995b), the star 3) is AH Vir a known W UMa star, while very little information is available for the star 4), its lithium abundance is consistent with that of RS CVn's and exclude a possible PMS nature. None (except for one of the reddest objects) of our sample stars has a position in the HR diagram which indicates that they are still undergoing pre-main sequence contraction.

4. Discussion

As discussed in § 2, the sub-sample of the EMSS discussed here is biased toward the optically brighter and less X-ray active stars. Such a bias has to be taken into account to be able to extend the results about the evolutionary stage of our sub-sample to the whole EMSS stellar population.

Keeping this bias in mind, we will draw some conclusions about the nature of the young X-ray selected stars, taking advantage of the available lithium abundance measurements. The presence of a high lithium abundance in cool Pop. I dwarfs is considered an unambiguous indicator of youth. The lithium present on the stellar surface is in fact expected to be transported by the convective mo-

Table 1. Properties of the EMSS stars observed by Hipparcos. The original name in the EMSS is given, as well as the number in the Hipparcos Catalogue (HIP) and the HD number. For the cases in which the star had no HD number other common catalog names for the object are reported. The photometry and distance, with the associated errors, are those reported in the Hipparcos Catalogue, while the quantities f_x/f_v, M_v, and $\log(L_x)$ have been recomputed using the Hipparcos photometric and parallax measurements. N(Li) is the lithium abundance from Favata et al. (1993, 1995a).

EMSS Name	HIP	HD	m_v	$B-V$	$\log(f_x/f_v)$	N(Li)	Dist. [pc]	Err %	M_v	$\log(L_x)$ [erg/s]
MS0002.8+1602	451	42	8.63	0.46	−3.53	2.50	219.8	21.8	1.92	30.28
MS0003.3−4201	490	105	7.51	0.60	−3.59	3.40	40.2	3.7	4.49	29.20
MS0004.0+2844	544	166	6.07	0.75	−3.50	...	13.7	1.0	5.39	28.93
MS0007.4+1051	813	560	5.54	−0.06	−4.34	...	99.6	8.6	0.55	30.02
MS0009.9+1417	999	SAO 91772	8.44	0.74	−2.69	1.35	40.5	4.9	5.40	29.74
MS0031.9−0646	2710	3126	6.90	0.48	−3.70	2.95	41.5	3.7	3.81	29.36
MS0138.0−5627	7751	10360	5.76	0.88	−4.58	<−0.95	8.2	1.2	6.21	27.52
MS0214.9+1813	10701	14147	7.43	0.30	−4.23	...	84.8	7.5	2.79	29.23
MS0234.2−0321	12158	16287	8.10	0.94	−3.68	<−0.05	24.3	3.0	6.17	28.43
MS0241.6+1045	12787	...	10.98	1.40	−1.86	...	33.6	10.1	8.35	29.38
MS0257.3+0733	13976	18632	7.97	0.93	−3.84	<−0.35	23.4	2.9	6.12	28.30
MS0300.1−1528	14157	18955	8.45	0.86	−3.78	<0.50	48.6	6.7	5.02	28.80
MS0326.6−2008	16212	SAO 168572	10.10	0.55	−2.88	2.90	228.8	44.6	3.30	30.38
MS0327.2−2416	16247	21703	9.15	1.02	−2.31	...	31.7	4.3	6.64	29.62
MS0337.6−0202	17132	22853	7.28	1.11	−4.09	<1.20	274.0	25.8	0.09	30.46
MS0356.9+1011	18658	25102	6.35	0.42	−4.17	...	39.3	4.1	3.38	29.06
MS0411.4+2327	19793	26736	8.05	0.66	−3.67	...	46.1	5.3	4.73	29.02
MS0413.7−6235	19780	27256	3.33	0.92	−5.18	1.30	50.1	2.3	−0.17	29.47
MS0430.6+1754	21251	28867	6.24	0.08	−3.66	...	129.7	17.4	0.68	30.65
MS0448.4+1058	22550	30810	6.79	0.54	−3.84	2.75	49.6	5.7	3.31	29.42
MS0457.5+0312	23245	31993	7.48	1.25	−3.79	2.05	238.1	26.0	0.60	30.55
MS0535.7−2839	26453	37484	7.26	0.40	−4.16	3.75	59.5	4.9	3.39	29.07
MS0535.7−2843	26460	37495	5.28	0.49	−4.51	...	42.5	2.6	2.14	29.21
MS0657.4+7518	34085	51067	7.15	0.59	−4.08	...	37.2	6.2	4.30	28.79
MS0657.4+7518	34087	SAO 6052	8.24	0.75	−3.64	...	33.9	12.6	5.59	28.71
MS0657.5+7529	34101	51066	6.99	0.94	−3.55	...	275.5	20.1	−0.21	31.12
MS0758.7+1411	39247	65916	8.40	0.79	−3.85	...	199.6	23.8	1.90	29.98
MS0810.2+6305	40380	SAO 14468	9.34	0.64	−3.59	...	78.6	10.5	4.86	29.04
MS0830.3+1126	41951	72429	7.95	0.72	−3.54	...	143.7	15.1	2.16	30.17
MS0842.6+1900	42970	74607	6.77	0.39	−4.47	...	62.7	5.4	2.78	29.00
MS0847.4+3328	43410	75332	6.22	0.55	−3.74	...	28.7	2.5	3.93	29.27
MS0851.1+2025	43701	SAO 80493	8.60	0.48	−3.67	...	99.3	12.7	3.62	29.46
MS0920.6+7838	46298	80388	8.33	0.59	−3.60	...	52.1	4.6	4.75	29.09
MS0920.6+7838	46299	80389	8.67	1.60	−3.46	...	57.5	6.2	4.87	29.17
MS0922.9−0610	46223	81421	7.01	0.28	−3.75	...	70.0	7.0	2.79	29.72
MS0924.3+3942	46383	GJ 343.1	9.86	1.28	−2.90	...	32.2	5.7	7.32	28.76
MS0948.2+0822	48309	85270	7.68	0.95	−3.90	<−0.23	184.8	18.1	1.35	30.15
MS0954.5+6717	48899	...	10.38	1.32	−2.45	...	33.2	5.9	7.77	29.03
MS1004.9+1316	49617	87777	8.38	0.58	−4.02	...	67.2	8.3	4.24	28.87
MS1019.8−1016	50796	BD−09 3055	10.80	1.19	−2.71	...	34.0	9.2	8.14	28.62
MS1022.3+1259	50990	90208	8.24	0.38	−3.84	...	137.7	14.3	2.55	29.72
MS1109.8+3605	54745	97334	6.41	0.60	−4.11	<1.50	21.7	2.0	4.73	28.58
MS1109.8+3605	54763	97371	7.20	1.02	−3.79	<1.50	131.2	12.3	1.61	30.15
MS1110.7−2611	54807	97528	7.27	0.14	−4.33	...	153.9	14.6	1.33	29.72
MS1127.8−1502	56139	100022	9.40	0.66	−2.80	...	119.3	14.4	4.02	30.18
MS1148.5+3533	57802	GJ 450	9.76	1.48	−3.22	...	8.6	1.2	10.10	27.32
MS1208.6+3924	59405	105881	8.03	0.43	−4.16	...	83.4	8.0	3.42	29.05
MS1211.8+1206	59683	106400	9.18	0.81	−2.91	...	92.1	28.6	4.36	29.93
MS1222.5+2549	60582	108102	8.12	0.53	−3.12	...	107.1	11.4	2.97	30.27
MS1254.8+0142	63235	112542	6.91	0.45	−4.30	2.40	59.0	5.0	3.05	29.06
MS1255.3+3529	63253	GJ 490A	10.57	1.42	−1.95	...	18.1	5.7	9.28	28.92
MS1256.2+3833	63317	112733	8.67	0.74	−2.72	1.15	44.4	6.4	5.43	29.69
MS1256.2+3833	63322	SAO 63275	9.28	0.85	−2.47	1.15	38.1	6.7	6.37	29.56
MS1309.7+3221	64405	114723	6.71	0.48	−4.38	1.90	78.0	11.5	2.25	29.31
MS1330.5−0811	66115	117860	7.35	0.62	−3.63	2.55	32.2	2.9	4.81	29.03

Table 1. Properties of the EMSS stars observed by Hipparcos (continued)

EMSS Name	HIP	HD	m_v	$B-V$	$\log(f_x/f_v)$	N(Li)	Dist. [pc]	Err %	M_v	$\log(L_x)$ [erg/s]
MS1332.6−2935	66563	118646	5.81	0.43	−3.68	...	49.0	3.9	2.36	29.96
MS1350.8+1810	67787	121107	5.71	0.85	−4.47	...	209.6	16.6	−0.9	30.47
MS1436.8−2628	71682	128787	6.99	0.47	−3.89	...	39.9	3.7	3.98	29.10
MS1436.8−2628	71686	SAO 182743	9.79	1.08	−2.77	<−0.05	39.8	9.7	6.79	29.10
MS1441.7+5208	71989	129920	8.22	0.66	−3.60	2.85	48.1	3.4	4.81	29.06
MS1520.2+2548	75233	136901	7.23	1.24	−4.05	...	279.3	24.9	0.00	30.53
MS1520.7−0625	75325	136905	7.29	1.05	−3.75	...	95.2	9.5	2.40	29.87
MS1521.1+3027	75312	137107	4.99	0.58	−5.09	2.55	18.6	2.3	3.64	28.04
MS1528.5+0844	75971	138290	6.57	0.38	−3.95	...	50.7	4.7	3.05	29.42
MS1533.0+0919	76319	139017	8.13	1.18	−3.51	...	411.6	48.6	0.06	31.05
MS1534.7+5448	76376	139493	5.77	0.05	−4.60	...	75.6	4.0	1.38	29.43
MS1559.2−2232	78549	143600	7.33	0.08	−3.67	...	121.1	10.9	1.91	30.15
MS1634.7+2638	81349	149931	7.92	0.46	−3.27	2.45	79.7	10.0	3.41	29.95
MS1635.0+2651	81370	149973	8.02	0.51	−3.61	...	67.8	6.7	3.86	29.43
MS1640.5+6224	81679	151067	7.16	0.12	−3.90	...	200.4	11.4	0.65	30.42
MS1704.3+5432	83608	154905	4.91	0.47	−4.17	2.45	27.0	2.4	2.76	29.31
MS1709.1+5432	83988	155674	8.85	1.15	−3.20	...	21.2	4.0	7.22	28.50
MS1709.1+5432	83996	GJ 659B	9.34	1.26	−3.00	...	20.9	6.5	7.74	28.49
MS1719.4+2650	84794	GJ 669B	11.26	1.63	−2.30	...	12.1	7.3	10.86	27.95
MS1737.2+6847	86201	160922	4.77	0.43	−4.33	2.70	23.5	1.2	2.92	29.09
MS1751.0+7046	87311	...	9.70	1.15	−2.22	...	349.7	32.5	1.98	31.57
MS1753.5+1830	87768	GJ 698	9.22	1.18	−3.30	<−0.20	23.0	5.1	7.41	28.32
MS1810.3+6940	89005	165814	8.60	0.94	−3.17	0.45	31.0	2.2	6.15	28.95
MS1849.2+7953	92040	175938	6.40	0.30	−4.51	...	88.3	4.7	1.67	29.40
MS2302.4−4427	114000	218023	9.83	0.71	−2.83	1.25	139.9	32.2	4.10	30.11
MS2332.4+0119	116384	GJ 900	9.59	1.33	−2.62	...	19.3	3.4	8.16	28.69
MS2335.2+0305	116600	222111	7.30	0.46	−3.96	<1.75	68.6	7.3	3.12	29.37

tions to the inner regions where the temperature is higher than the Li fusion temperature ($\sim 2.5 \cdot 10^6$ K) depleting the initial lithium with an efficiency dependent on the depth of the convection envelope and thus on stellar mass. Wichmann et al. (1996) have used a criterion based on the equivalent width of the lithium doublet at 6708 Å to select the PMS candidates from the optical counterparts of the RASS stellar sources around a number of SFR's. In particular, they have applied a 100 mÅ threshold in the equivalent width to select their PMS candidates at all spectral types later than F0. As outlined by Briceño et al. (1997) and as discussed by Favata et al. (1997) this choice includes also all the G and early K stars that have already reached the main sequence, but which are younger than $\approx 10^8$ yr. In Fig. 5 we plot the lithium abundance for the sample stars (from Favata et al. 1993, 1995a) versus the $B-V$ color. The solid line represents the 100 mÅ threshold used by Wichmann et al. (1996) to select the PMS candidates. Four of our sources appear to fulfill this criterion, and thus would be considered as PMS candidates adopting the Wichmann et al. criterion (they are plotted as filled squares in Fig. 5 and in Fig. 4). To enlarge the statistics on the behavior of these active-high lithium stars we have added to our EMSS sample 4 stars from the *Einstein* Slew survey (ESS, Elvis et al. 1992, Schachter et al. 1996), also with lithium equivalent width (Favata et al. 1995a) larger than 100 mÅ (the filled diamonds of Fig. 5 and of Fig. 4), for which we had the Hipparcos data available. The relevant properties for the Slew survey stars discussed are summarized in Table 2. From their position in the HR diagram we can assess that seven (three from EMSS and four from the Slew survey) of these "high lithium" PMS candidates are indeed main sequence stars, while the remaining star is on the giant branch.

All the stars (including the one source which satisfies the "Wichmann criterion" for high lithium star) which in our HR diagram fall on the giant branch have large implied bolometric luminosities, which places them on, or above the birth-line computed by Palla & Stahler (1993). Thus, if they were PMS stars they would be extremely young (with an age of $\lesssim 10^5$ yr, according to their positions on the evolutionary tracks of D'Antona & Mazzitelli 1994) and massive. This is quite unlikely, as such young stars would, by all plausible models, only be found within a SFR, and not spread around in the field. It is worth remarking that the lithium abundance of the "high lithium giant" discussed here is only n(li) ~ 2, not uncommon for active giants, but much lower than that normally found in PMS stars, which have a lithium abundance close to the "cosmic" value n(li) $\sim$ 3.2. Thus there is no reason, on the basis of the lithium abundance, to classify it as PMS.

We conclude that bona fide PMS stars are completely absent from our sample, with the possible exception of one object (MS0920.6+7838, for which however no lithium abundance measurements are available).

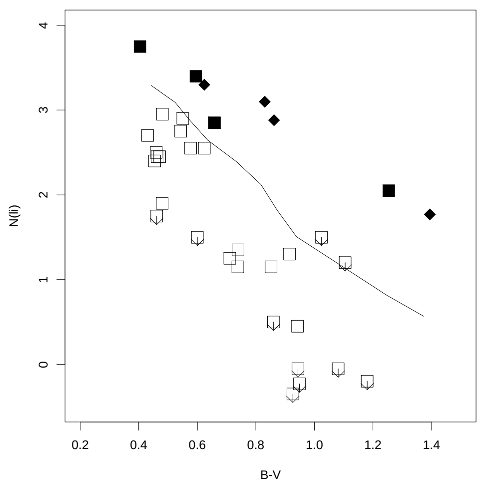

Fig. 5. Lithium abundance versus $B-V$ color for our subsample. The solid line is the threshold of 100 mÅ for the equivalent width of the lithium doublet used by Wichmann et al. (1996) to select PMS candidates. Filled symbols represent stars (squares are stars from the EMSS, while diamonds are from the slew survey), which, according to the Wichmann (1996) criterion, are probable PMS stars (while none of them is a true PMS, see their position in Fig 4).

As a further addendum, note that here we have applied the Wichmann criterion using the equivalent width of the lithium doublet obtained from high resolution spectra (R$\sim$ 50 000), while Wichmann et al. (1996) and Alcalá et al. (1996a, 1996b) have used low resolution spectra (4–8Å) that typically overestimate, at least in G and K stars, the equivalent width of the lithium doublet at 6708 Å by up to few tenths of Angstroms (Favata et al. 1997). It is thus likely that if we would use low resolution spectra, many more stars would be considered PMS stars following the Wichmann criterion, while we have not evidence of a major PMS population in our sample.

The X-ray luminosities (now based on the accurate Hipparcos distances) of our main sequence stars are very similar or slightly smaller than those of Pleiades stars of similar spectral type (Micela et al. 1990, 1996, Stauffer et al. 1994). Thus, all the available properties (their clear main sequence status, their moderate lithium abundances and their X-ray luminosity) are fully consistent with the hypothesis that they are young main sequence stars. Since this young main sequence star population is scattered everywhere in the sky, we expect to find stars of the same nature also near SFR. As a result, we expect that a sizeable fraction of the detected stars in the RASS, are not PMS stars, but they are indeed young main sequence stars, such as those of the EMSS.

To conclude, our data show that in our EMSS and ESS sample the fraction of PMS stars is negligible, with most main-sequence stars being young, Pleiades-like stars and giant stars either being normal giants or members of active binaries. Also, they show that the usage of simplistic criteria for the attribution of "PMS status" to activity selected stars can lead to the inclusion of stars which are clearly well into the main-sequence stage or even in the giant stage, and thus, as discussed in detail by Favata et al. (1997), to the possible overestimation of the PMS population in X-ray surveys.

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Table 2. Properties of the high lithium stars detected in the *Einstein* Slew Survey and observed by Hipparcos

SLEW Name	HIP	HD	m_v	$B-V$	$\log(f_x/f_v)$	N(Li)	Dist. [pc]	Err %	M_v	$\log(L_x)$ [erg/s]
ES0250−129	13402	17925	6.05	0.86	−3.55	2.88	10.4	0.8	5.97	28.64
ES0457+017	23200	GJ 182	10.05	1.39	−1.59	1.77	26.7	6.8	7.92	29.82
ES0528−654	25647	36705	6.88	0.83	−2.11	3.10	14.9	0.8	6.01	30.07
ES0637−614	31711	48189	6.15	0.62	−2.99	3.30	21.7	1.4	4.47	29.80

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