HIPPARCOS DISTANCES OF X-RAY SELECTED STARS: IMPLICATIONS ON THEIR NATURE AS STELLAR POPULATIONS

G. Micela[1], **F. Favata**[2], **S. Sciortino**[1]

[1]Osservatorio Astronomico di Palermo, Palazzo dei Normanni, 90134 Palermo, Italy
[2]Astrophysics Division – Space Science Department of ESA, ESTEC, 2200 AG Noordwijk, The Netherlands

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 $|b| > 20°$, 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 $\simeq 20$ per cent being giants. We do not find a significant presence of pre-main sequence stars in our sample, notwithstanding the fact that some of the stars have a considerable lithium abundance, showing that they are most likely young and active main-sequence objects.

Key words: Active stars; Stellar populations.

1. INTRODUCTION

Analysis of the stellar samples detected in X-ray flux limited surveys has led 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 means of selecting young active stars which would otherwise be hardly distinguishable from 'normal' stars (except through high-resolution optical spectroscopy).

One of the current problems in assessing the nature of the X-ray selected stars is if they belong to a young (Pleiades-like) main sequence population or to a population of Pre-Main Sequence (PMS) stars, such as the Weak T Tauri Stars (WTTS). These two populations 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 them. The most important difference between the two populations is their position on the HR diagram, which, if accurately determined, allows to immediately assess their evolutionary status.

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 the X-ray selected stellar populations of late-type stars.

2. THE SAMPLE AND THE DATA

The sample discussed here is the subsample of the EMSS stellar sample included in the Hipparcos Input Catalogue (HIC, Turon et al. 1992).

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 uncertainty. This process yielded a total of 84 EMSS stars which have been observed by Hipparcos.

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, 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, the subsample of the EMSS discussed here has a specific interest: the main peculiarity of the stellar content 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 the Galaxy (Favata et al. 1992, Micela et al. 1993, Sciortino et al. 1995) based on the X-ray emission of nearby stars and 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. Since the original discussion of this excess a number of photometric (Morale et al. 1996) and high resolution spectroscopic (Favata et al. 1993, 1995a) stud-

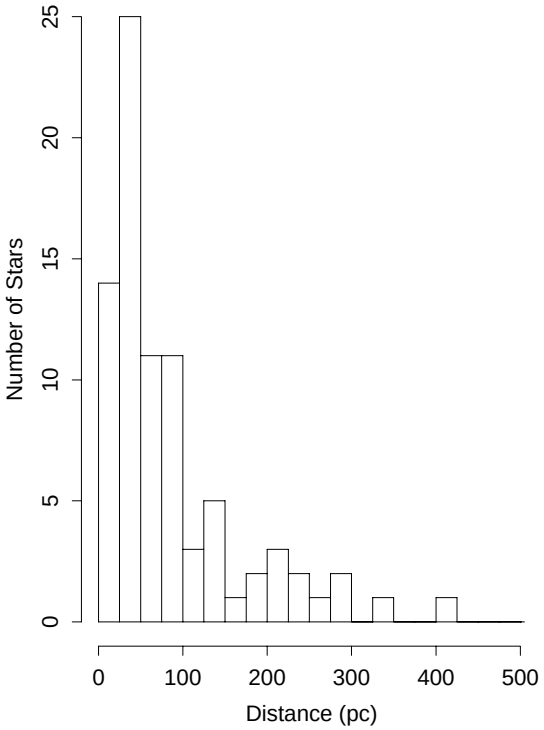

Figure 1. The distance distribution of stars in our sample obtained using the Hipparcos parallaxes. Note the peak of stars with distance less than 50 pc.

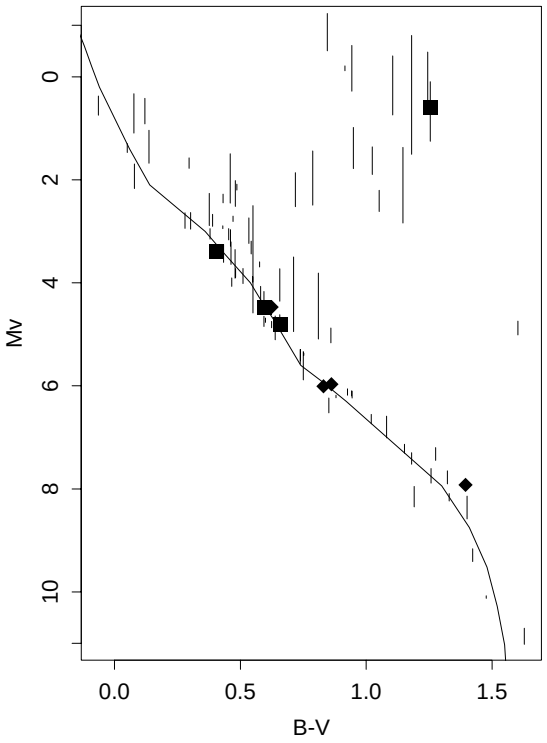

Figure 2. HR diagram for the EMSS stars observed by Hipparcos. Vertical lines are the errors in the absolute magnitude due to the errors in Hipparcos distances. The continuous line is the main sequence (Keenan 1963, Johnson 1965) and filled squares represent high lithium stars from the EMSS, while filled diamonds are the high lithium stars from the Slew survey (see text).

ies have been conducted 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.

The ranges of apparent magnitude and of f_x/f_v where the excess population is concentrated correspond to those of the sample for which the Hipparcos data are available, hence we are confident that our sample 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

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 per cent have been included. This restriction excludes only 2 objects from the sample. The distance distribution of the sample is shown in Figure 1. Note that half of the stars have distances less than 50 pc, and 75 per cent less than 100 pc.

Starting from the Hipparcos parallax and from the V magnitude reported 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.

The absolute magnitude and the $B-V$ colour have been used to generate the HR diagram for our sample stars, which is shown in Figure 2. 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 in the following.

Inspection of Figure 2 shows that the majority of the stars in our sample are main sequence objects, with a fraction (about 20 per cent) lying on the giant branch. 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. 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. Star (2) is a typical RS CVn (Favata et al. 1995b), star (3) is AH Vir, a known W UMa star. While very little information is available for 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

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 motions to the inner regions where the temperature is higher than the Li fusion temperature ($\simeq 2.5\times10^6$ 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 Figure 3 we plot the lithium abundance for the sample stars (from Favata et al. 1993, 1995a) versus the $B-V$ colour. 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 Figure 2 and in Figure 3).

To enlarge the statistics on the behaviour 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 Figure 2 and of Figure 3 for which we had the Hipparcos data available). 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.

We conclude that *bona fide* PMS stars lying on the Hayashi track 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, see also Favata et al, this volume).

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 proximity to the main sequence, their moderate lithium abundances and their X-ray luminosity) are fully consistent with the hypothesis that they are young (near) main sequence stars.

To conclude, the 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. Giant stars are either normal giants or members of active binaries.

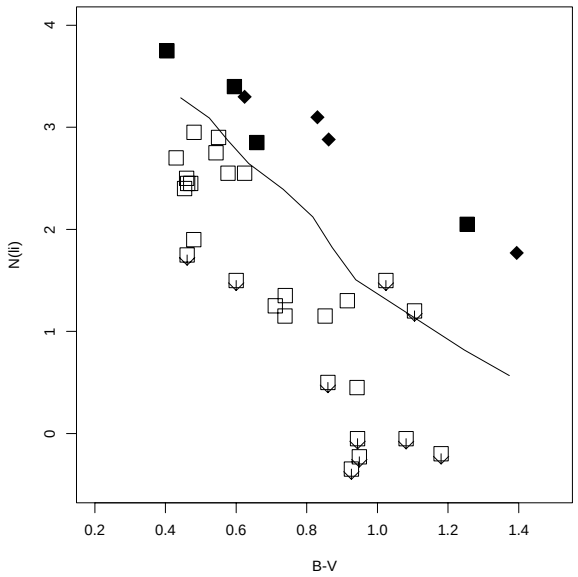

Figure 3. Lithium abundance versus B-V colour for our subsample. The solid line is the threshold of 100 mÅ for the equivalent width of the lithium doublet used by Wichmann et al. (1996) to select PMS candidates. Filled symbols represent stars (squares are stars from the EMSS, while diamonds are from 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 Figure 2).

ACKNOWLEDGEMENTS

G.M. and S.S. acknowledge financial support from ASI (Italian Space Agency), and MURST (Ministero della Università e della Ricerca Scientifica e Tecnologica). We would like to thank M.A.C. Perryman for some useful discussions on Hipparcos data and M. Lattanzi for dealing with the Hipparcos consortium on our behalf.

REFERENCES

Bahcall, J. N., Soneira, R. M., 1980, ApJS, 44, 73

Briceño, C., Hartmann, L. W., Stauffer, J. R., Gagné, M., Stern, R. A., Caillault, J-P., 1997, AJ, 113, 740

Elvis, M., Plummer, D., Schachter, J., Fabbiano, G., 1992, ApJS, 80, 257

Favata, F., Rosner, R., Sciortino, S., Vaiana, G.S., 1988, ApJ, 324, 1010

Favata, F., Barbera, M., Micela, G., Sciortino, S., 1993, A&A, 277, 428

Favata, F., Barbera, M., Micela, G., Sciortino, S., 1995a, A&A, 295, 147

Favata, F., Micela, G., Sciortino, S., 1995b, A&A, 298, 482

Favata, F., Micela, G., Sciortino, S., 1997, A&A, in press

Fleming, T., Gioia, I., Maccacaro, T., 1989, AJ, 98, 692

Johnson, H. L., 1965, ApJ, 141, 170

Keenan, P. C., 1963, in Basic Astronomical Data, Strand, K. ed., (Chicago: University of Chicago Press), 78

Micela, G., Sciortino, S., Vaiana, G.S., et al., 1990, ApJ, 348, 557

Micela, G., Favata, F., Sciortino, S., 1993, ApJ, 412, 618

Micela, G., Sciortino, S., Kashyap, V., Harnden, F.R. Jr., Rosner, R., 1996, ApJS, 102, 75

Morale, F., Micela, G., Favata, F., Sciortino, S., 1996, A&AS, 119, 403

Schachter, J. F., Remillard, R., Saar, S. et al., 1996, ApJ, 463, 747

Sciortino, S., Favata, F., Micela, G., 1995 A&A, 296, 370

Stauffer, J.R., Caillault, J.-P., Gagné, M., Prosser, C.F., Hartmann, L.W., 1994, ApJS 91, 625

Turon, C., Crézé, M., Egret, D., et al., 1992, ESA SP–1136, Vol. I-VII

Wichmann, R., Krautter, J., Schmitt, J.H.M.M., et al., 1996, A&A, 312, 439