ROSAT PSPC/HRI observation of the young open cluster NGC2422

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ABSTRACT

We present the preliminary results of a ROSAT study of NGC 2422, a southern open cluster at a distance of about 400 pc, with an age slightly younger than the Pleiades. Source detection was performed on two observations, a 10-ksec PSPC pointing and a 40-ksec HRI pointing, with PSPC and HRI analysis performed using a new detection algorithm based on wavelet transforms.

Our list of X-ray detections consists of 101 sources, 35% of which were detected only with the HRI, while 30% appeared only in the PSPC data. For each source, we have computed the 0.2-2.0 keV un-absorbed X-ray flux, 0.2-2.0 keV X-ray luminosity, and hardness ratio (PSPC only).

A campaign of optical low-dispersion spectroscopic observations is underway, using the 1.5 m ESO (La Silla) telescope to identify optical counterparts for the X-ray sources. To date, candidate optical counterparts have been found for about 50 X-ray sources, with more than half of these being late type (F-G) stars. Further observations are planned to complete the identification program.

INTRODUCTION

The study of galactic open clusters provides ideal samples of age-homogeneous solar-type (F, G and K) stars, which can be used to study the age evolution of several parameters and their inter-relationship. Well studied parameters include stellar activity (as expressed by the X-ray luminosity), projected rotation velocity ($v\sin(i)$), and surface lithium abundance. The present knowledge of the evolution of the above parameters with stellar age for late type stars is essentially based on the extensive study of a limited number of open galactic clusters like the Pleiades, Alpha Per, the Hyades, Praesepe, and the Ursa Major stream. The study of additional open clusters, both from the X-ray and from the optical point of view, is of great importance to consolidate the current picture of late type stars activity evolution.

One of the most promising open clusters of age close to the Pleiades is NGC 2422, a southern cluster of medium richness with a diameter of about 30 arcmin, at a distance of about 400 pc (Shobbrook 1984).

In this poster we present preliminary results from the study of two pointed X-ray observations of NGC2422, conducted with the ROSAT PSPC (10 Ksec) and with the ROSAT HRI (40 Ksec) detectors. Results are also presented from an on-going campaign of optical spectroscopic observations carried to identify likely counterparts of X-ray sources.

X-RAY MEASUREMENTS

The PSPC and HRI observations have been analyzed using the automated pipeline processing described in Mackie et al. (1995). This pipeline includes data screening to cut high background time intervals (Bocchino et al. 1995), wavelet transform based detection algorithm (Damiani et al. 1995), detected sources count-rate determination, counterpart identification with a list of objects taken from a compilation of multi-wavelength catalogues, upper-limit determination on un-detected objects, and spectral analysis on bright sources.

The un-absorbed X-ray flux in the 0.2-2.0 keV energy band has been calculated from the measured count-rates adopting a single temperature ($10^7\ K$) Raymond-Smith emission model with $Nh = 3.3 \times 10^{20}\ cm^{-2}$ derived using the expression $Nh = 2.22 \times 10^{21} \times 3 \times E_{B-V}$ (Gorestein 1975) with $E_{B-V} = 0.05$ (Smyth & Nandy, 1962). A cluster distance of

$400 \pm 10\ pc$ (Shobbrook 1984) has been used to determine the 0.2-2.0 keV X-ray luminosities.

We have detected 63 sources with $SNR > 4$ in the 8877 seconds PSPC screened observation (9095 seconds live time), and 67 sources in the 37800 sec HRI screened observation (38075 live time). Our final X-ray list contains both PSPC and HRI sources; in particular, 34 HRI sources positionally matching with at least one PSPC source, 36 HRI sources with no PSPC counterpart and 31 PSPC sources with no HRI counterpart, for **a total of 101 X-ray sources**. The positional matching has been carried out using the PSPC PSF 90% encircled energy radius as positional error in the PSPC coordinates. **Figure 1** is the $1°$ radius PSPC smoothed X-ray image with PSPC sources error circle overlaid, and **figure 2** is the $\sim 35' \times 35'$ HRI smoothed X-ray image with HRI (boxes) and PSPC (circles) detected sources overlaid. The size of the boxes identifying HRI sources is the scale corresponding to maximum SNR detection according to adopted wavelet transform detection algorithm.

Notice that most of the PSPC sources with no HRI counterpart are detected outside the HRI central part of the FOV while most of the 36 HRI sources with no PSPC counterpart are found in the central part of the FOV, where the flux sensitivity threshold of the HRI observation is lower with respect to the PSPC observation. This is better shown in **figure 3**, which is the map of the ratio between the HRI and the PSPC flux sensitivity threshold with sources overlaid. Nevertheless, some of the cases of single instrument detection are not explained in terms of different instrumental sensitivity, and we are currently investigating the possibility of flares and HRI UV leaks occurrence.

In **Table 1** we report a list of X-ray measurements of the sources in our complete PSPC/HRI catalogue. We report **position** (both HRI and PSPC), **offset** (in case of source matching), **0.2-2.0 keV un-absorbed X-ray flux** (weighted average of the PSPC and HRI values for matching sources), **0.2-2.0 keV X-ray luminosity**, **hardness ratio** (only PSPC), and **optical identification** where available. A level of reliability on the optical identification is also given, namely *** = certain, ** = very likely, * = likely.

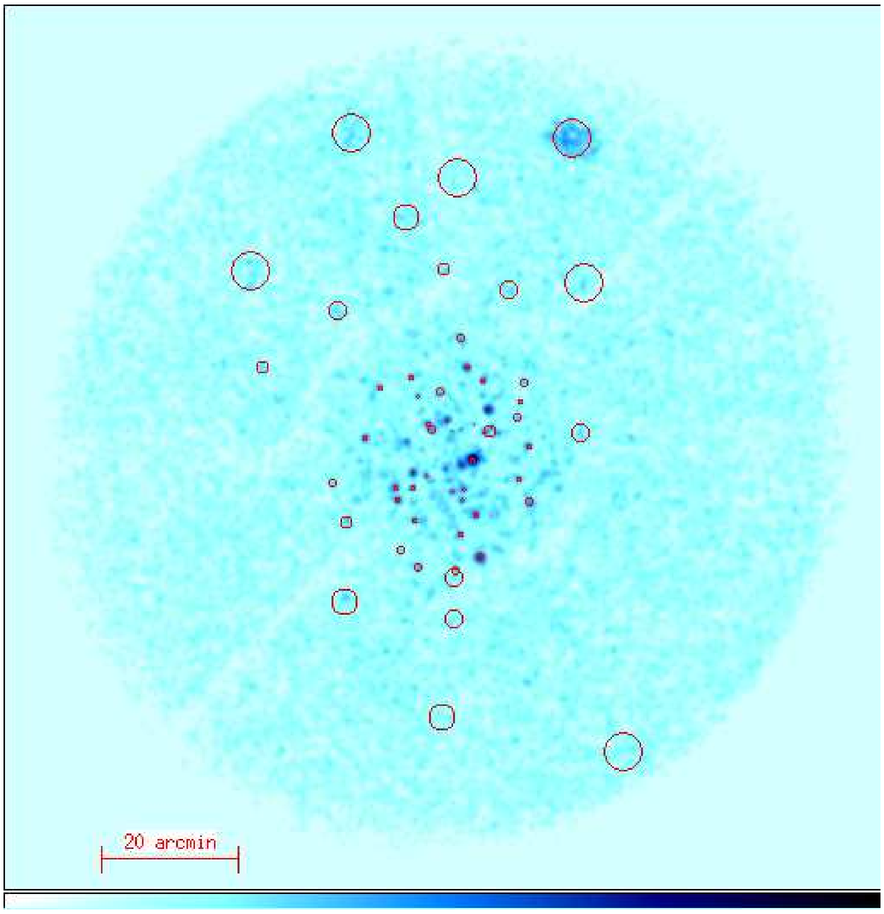

Figure 1: Smoothed X-ray image of the PSPC 10 ksec observation pointed to NGC2422. The X-ray sources detected with the wavelet transform detection algorithm are identified by 90% PSF encircled energy radius circles that have been used for the positional matching with the HRI source list.

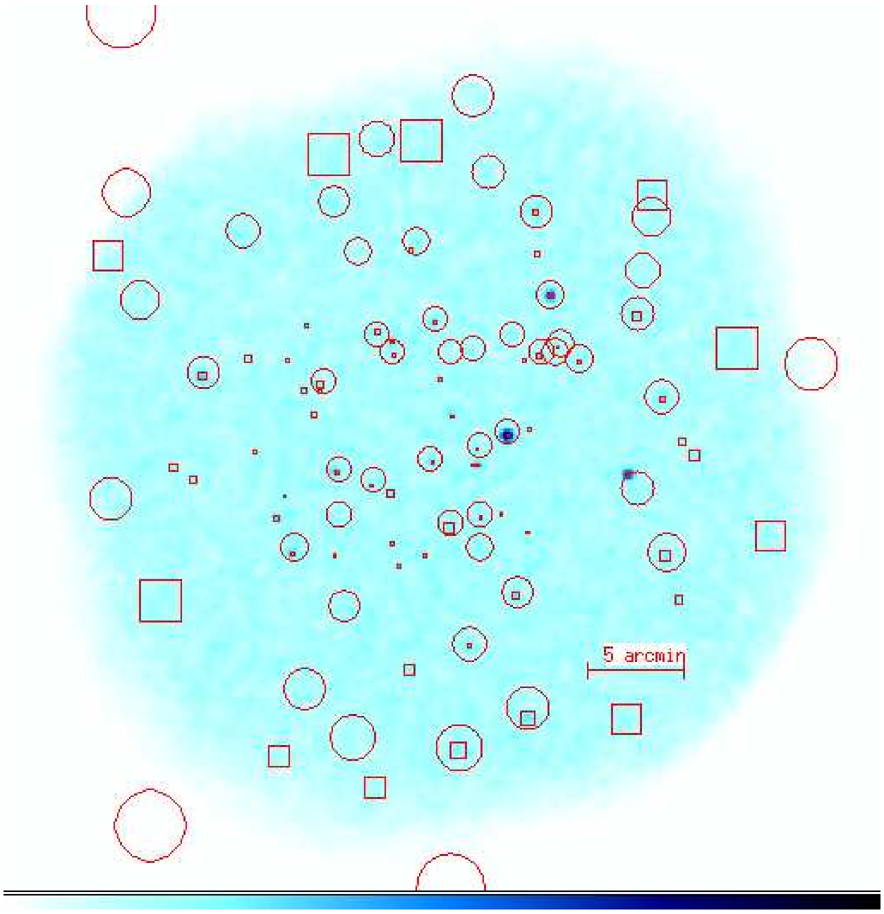

Figure 2: Smoothed X-ray image of the HRI 40 Ksec observation pointed to NGC2422. The X-ray sources detected with the wavelet transform detection algorithm are identified by squares of size equal to the wavelet scale of maximum SNR. Superimposed are also the PSPC sources (circles). Notice that most of the sources detected only with the PSPC fall outside the central region of about 20 arcmin diameter where the HRI observation is more sensitive with respect to the PSPC one.

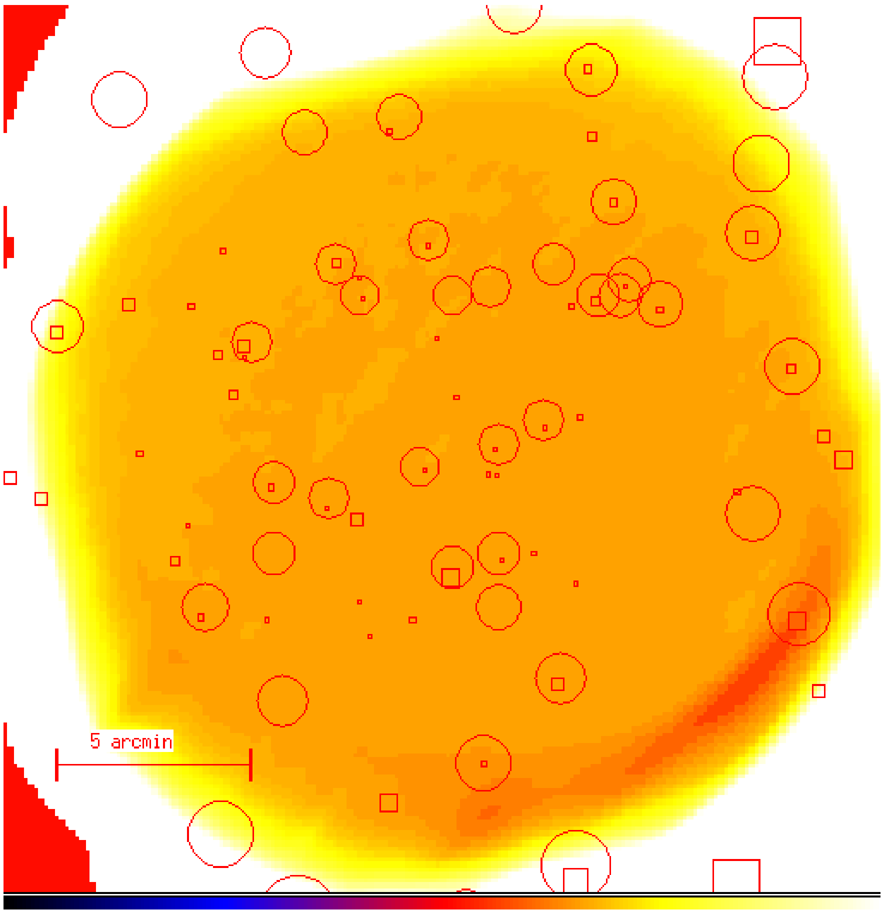

Figure 3: Map of the ratio between threshold flux sensitivity of the HRI exposure (37800 sec) and PSPC exposure (8877 sec) in the HRI field of view according to the adopted wavelet transform detection Algorithm. In the central region, about 20 arcmin diameter, the HRI is more sensitive than the PSPC with flux sensitivity, in the 0.2-2.0 keV energy band, two times lower (orange) on average with respect to the PSPC. Outside this central region the PSPC becomes much more sensitive than the HRI (yellow, white).

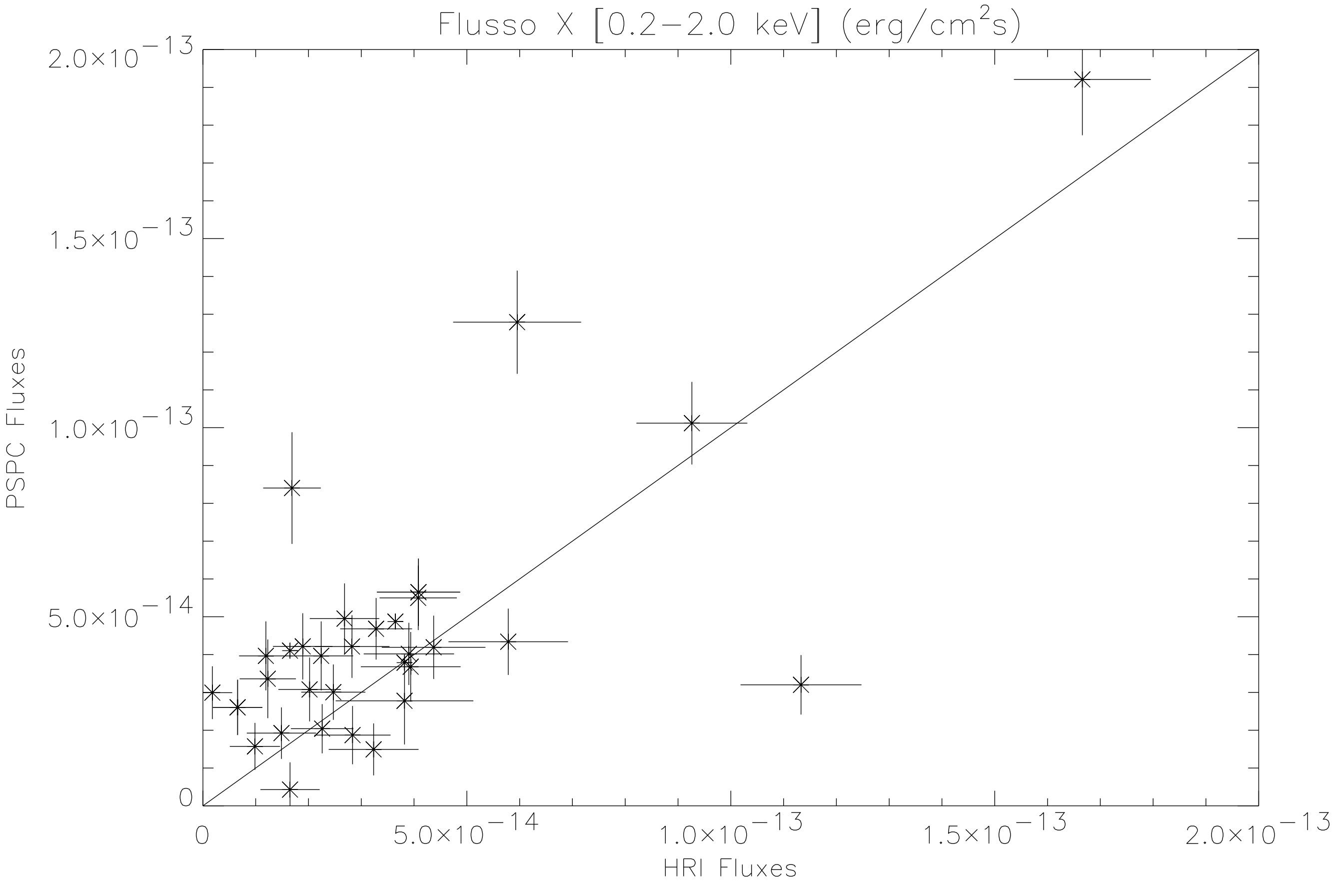

Figure 4: Scatter plot of the X-ray flux measured with the HRI and PSPC for the sources detected with both instruments.

OPTICAL MEASUREMENTS

The lack of existing optical catalogs going to deep enough magnitudes in the cluster NGC2422 has made it necessary to carry out a detailed program of spectroscopic observations for the purpose of identifying the optical counterparts to the X-ray sources. The optical identification program has been conducted by making an effort to take an optical low resolution spectrum, for each X-ray source, of all the possible counterpart within the limiting magnitude of the telescope used (**see for example figure 6**). The observations were carried out at the ESO 1.5m telescope, using the B&C spectrograph, at an effective 2 pixel resolution of about 4 $\AA$, and with a coverage from $\sim$ 3700 $\AA$ up to $\sim$ 7000 $\AA$. The effective limiting magnitude was about 16 in the V band.

The observations spanned 6 nights (2 in Feb. 1994, 4 in Feb. 1995), and about 150 possible counterparts to the 67 PSPC SASS sources were observed. In most cases all the optical sources in the PSPC error circles (EC) were observed, although few of the potential counterparts were not observed because of bad weather at the end of the run. Optical observations were conducted on the basis of the plausibility of the source as counterpart: optical to X-ray luminosity ratios (as appropriate for the spectral type of the potential counterpart) are considered first as a screening factor; this alone provides a plausible, single counterpart identification for over half of the sources. It should be noted that at this spectral resolution (and given the low sensitivity of the ESO 1.5m CCD in the blue) no signs of stellar activity (i.e. Ca II emission cores) are visible in the majority of the counterparts, although some of the later type ones have (partially) filled in Hα lines. A few of the sources have clear counterparts as dMe/dKe stars.

About one third of the sources have multiple potential optical counterparts based on their PSPC positions. The HRI observation of the central field of view of the PSPC, while confirming all of the “firm” identification of the PSPC sources, has helped in most of the cases to select the actual counterpart in the ambiguous cases (**see for example figure 6**).

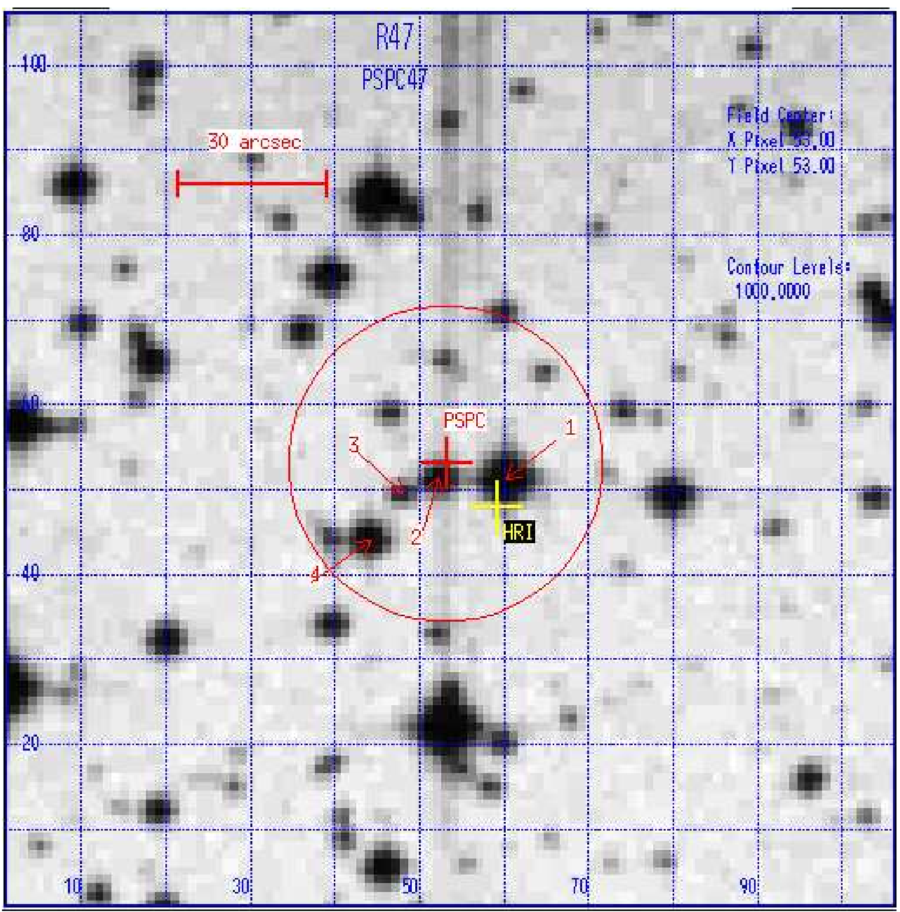

Figure 5: Several optical sources of different magnitudes crowd the 30 arcsec error circle (EC) centered on the PSPC X-ray source N. 10 in table 1 (red cross). Sources 1 and 2 are both mid-F sources, and are reasonably close to the PSPC EC center. Source 3 is a late B star too faint to be a cluster member, while source 4 is again a mid-F source. Both sources 1 and 2 are the most plausible counterparts to the PSPC source. The HRI source (yellow cross) is dead on source 1 which thus appears as the most likely optical counterpart.

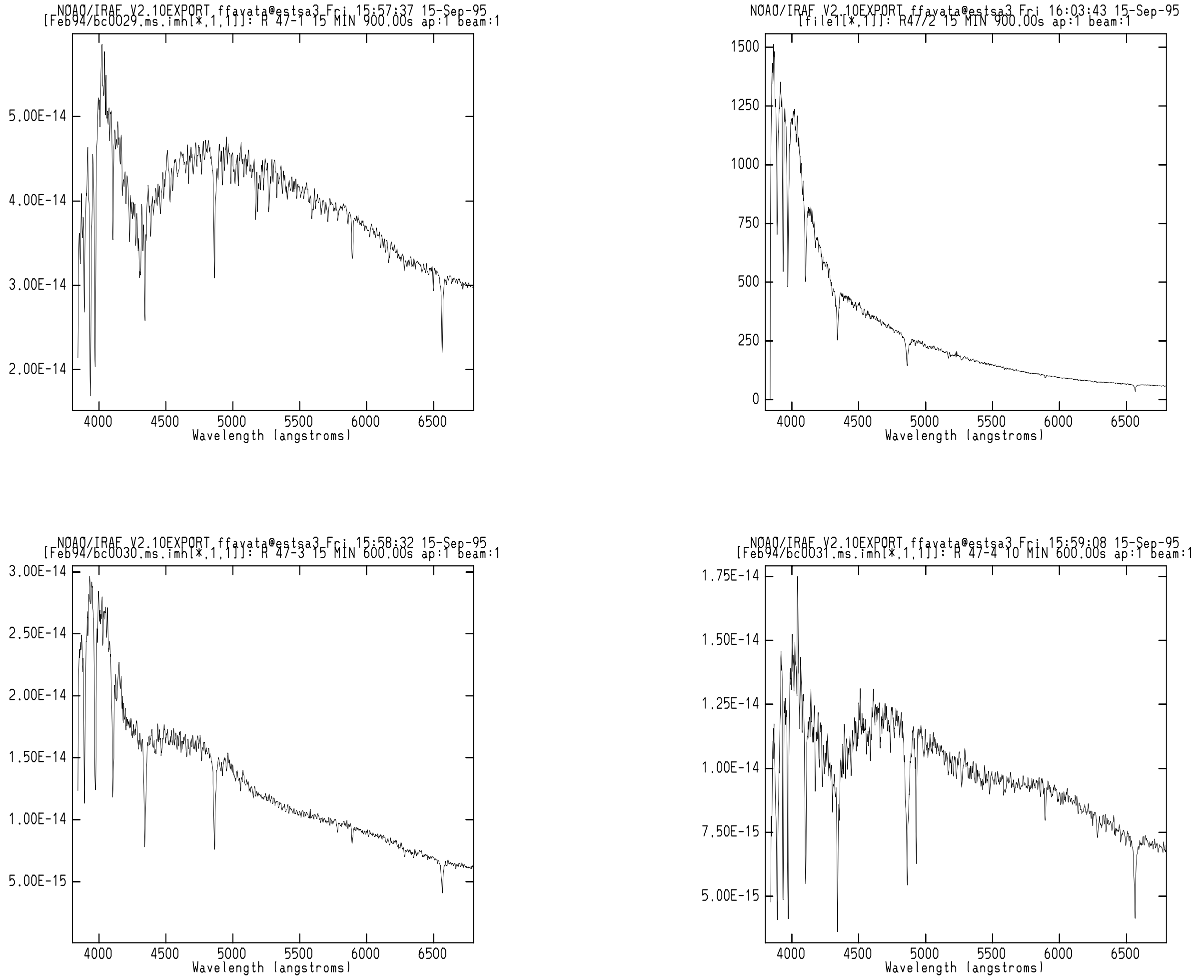

Figure 6: Optical low dispersion spectra of four sources within 30 arcsec from the PSPC X-ray source N. 10 in table 1. Sources 1 (top left), 2 (top right), and 4 (bottom right) are mid-F type, while source 3 (bottom left) is a faint late B star.

WORK IN PROGRESS

X-ray flux and luminosities of PSPC detected sources will be refined using the hardness ratio to better choose the model emission spectrum. A detailed analysis will be conducted for the sources detected with a single instrument not justified on the basis of different instrumental X-ray flux threshold.

The optical identification program will be carried on in order to complete the survey of detected X-ray sources both with the PSPC and HRI detectors. An analysis of the membership of NGC2422 is also being conducted with the use of first epoch archive astrometric plates and second epoch plates both new and from recent photometric sky surveys.

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