THE STELLAR X-RAY DATABASE OF EINSTEIN IMAGE OBSERVATIONS

G.Micela, A.Maggio, S.Sciortino, G.S.Vaiana
Osservatorio Astronomico di Palermo
F.R.Harnden Jr., R.Rosner
Harvard-Smithsonian Center for Astrophysics
J.H.H.M.Schmitt
Max Planck Institute fur Extraterrestrische Physik

Abstract

We present the database of the stellar X-ray results of the Einstein Observatory based on an uniform analysis of all the Imaging Proportional Counter fields obtained during the life of the HEAO-2 mission. The data are archived into an INGRES™ based relation database system so that interactive statistical analysis of the properties of the full stellar data set are feasible. Illustrative examples will furnish a general view of the kind and amount of archived information and of some recent scientific results.

1. The Einstein Stellar Database Content

In this paper we give a brief description of the database which we are using to study the properties of stellar X-ray emission as observed by the IPC (Imaging Proportional Counter) onboard of Einstein Observatory.

The data archived are the results of the latest processing of the observations (Harnden et al., 1984) and of stellar specially-designed processing. Data are stored in several relations of the relational database system INGRES, working both on SUN (at...
CiA) and DEC VAX (at Osservatorio Astronomico di Palermo) computers. The data are currently analyzed using "S" a statistical interactive graphic analysis system.

The IPC has observed ~ 4000 fields of 1 ' x 1 ' and has detected ~ 14500 X-ray sources. Table 1 shows some numbers that summarize data content in our database. The number of the detections is greater than the number of sources, because ~ 10% of sources has been observed more than once, we note also that a large number of sources are serendipitous, and that only the 10% of the total number of sources are pointed.

A third of the sources has been identified with a known counterpart. The identification has been performed with the objects listed in ~ 60 optical, radio, infrared catalogs merged in the Einstein Master Catalog; galactic catalogs include SAO catalog, Woolley, Kukarkin, catalogs of open cluster, OB stars catalogs, SNRs and Pulsars catalogs etc; extragalactic catalogs include Abell, Zwicky, NGC, Burbidge QSO catalogs; the two major radio catalogs included are Veron and Ohio Master catalogs.

One half of the identified X-ray sources have galactic counterparts and remaining X-ray sources have extragalactic counterparts. A few percentage of X-ray sources have ambiguous identification because the error circle contains both a galactic and an extragalactic objects. For these ambiguous cases and for about 10000 unidentified X-ray sources we plan to investigate if is possible to discriminate the "true" nature of the sources from optical and X-ray characteristics.

To conclude this description we note that our database contains also ~ 30000 upper limits evaluated at the positions of undetected optically known stars listed in all stellar catalogs of Einstein Master Catalog.

2. INGRES Database Structure

The data are stored in INGRES database system in 3 groups of relations: 1) logbook relations which consist of 9 main tables which maintain general information on processing (dates of processing, corrections, various notes and so on); 2) scientific relations which consist of 13 main tables which contain the basic scientific X-ray data; 3) support relations which contain optical catalogs as the Yale Bright Stars catalog, the Woolley catalog, open cluster catalogs, SAO and Kukarkin catalog.

The scientific relations are organized in 4 groups:

i) containing general information on images, such as center coordinates, exposure time, date of observation, information on intensity and spectrum of background, number of detections, etc.

ii) containing information on detections, such as position, signal to noise, flux, hardness ratio, spectrum of detection, etc.

iii) containing information on identifications if available, such as name and catalog of the counterpart, visual magnitude, offset, etc.

1 In the present context the word "detection" refer to each X-ray observation in which a source has been revealed.
### TABLE 1
SUMMARY OF OBSERVATIONS

<table>
<thead>
<tr>
<th>NUMBER OF FIELDS</th>
<th>3996</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER OF DETECTIONS</td>
<td>16645</td>
</tr>
<tr>
<td>pointed</td>
<td>1742</td>
</tr>
<tr>
<td>NUMBER OF SOURCES</td>
<td>14631</td>
</tr>
<tr>
<td>observed once</td>
<td>13342</td>
</tr>
<tr>
<td>more than once</td>
<td>1289</td>
</tr>
<tr>
<td>NUMBER OF IDENTIFIED SOURCES</td>
<td>4033</td>
</tr>
<tr>
<td>Galactic</td>
<td>1923</td>
</tr>
<tr>
<td>Extragalactic</td>
<td>1891</td>
</tr>
<tr>
<td>Uncertain</td>
<td>219</td>
</tr>
<tr>
<td>NUMBER OF UPPER LIMITS</td>
<td>31735</td>
</tr>
</tbody>
</table>

iv) containing information on upper limits, such as name and catalog of the object for which has been evaluated the upper bound, visual magnitude, the 3σ upper limit to the count/rate, etc.

Of course each user can build its own relations starting from those containing general data.

Fig. 1 shows the sky coverage of the IPC, symbol dimension is of the same order of effective coverage of one IPC images (the true field of view is squared). Entire coverage is about 10% of the sky and is highly inhomogeneous, indeed are evident several structures due to the oversampling of particular regions as the galactic plane, the Large and Small Magellanic Clouds, the Cignus Loop, the Vela Supernova Remnants and the NEP region.

The coverage is also inhomogeneous in sensitivity, in Fig. 2 are plotted the threshold values (expressed in count rate) evaluated at stellar positions (in absence of X-ray detection) versus the observation time, note that the threshold value spans a range of \( \sim 1.5 \) order of magnitude.
Fig. 1 - Galactic coordinates sky projection of the coverage attained by the Einstein Observatory IPC images, each image is represented by one circle, whose area is equal to the projected image area. Note that the actual IPC field of view is a (rotated) square.

Fig. 2 - Threshold values (expressed in count rate), evaluated at those stellar positions without positive X-ray detection, versus observation time.

3. Some Scientific Applications

One of the scientific application which we are presently working on is the systematic and homogeneous study of the X-ray emission from open cluster.
The Hyades has been the first target of this project; this study has involved 63 IPC images with more than 300 detections. One of the results of this survey is illustrated in Fig. 3 where mean value of the logarithm of the X-ray luminosity is plotted versus the color index. We note that 1) mean value of X-ray emission decreases with the increasing of age, and 2) dependence of $L_x$ vs. B-V depends on age. Analogous works are in progress for the Pleiades, UMa Clusters, S Mon and θ Car.

![Graph](image.png)

Fig. 3 - Summary of the behavior of $<\log(L_x)>$ as function of spectral type and stellar age, as deduced from volume limited sample of nearby stars, and analysis of samples of coeval stars.

Another work in progress which use largely the *Einstein* Stellar Database is the study of long term X-ray sources variability for those sources observed more than once. The Fig. 4a shows, for a sample of 603 sources, the integral distribution of the fraction of sources for which we can reject the null hypothesis of source constancy at given confidence level; there is a clear excess of sources for which the null hypothesis is rejected at each confidence level. In particular at 99% confidence level the number of sources for which we reject the null hypothesis is $\sim 40\%$, very high respect to $1\%$ expected in a sample of truly constant sources.

The variability do not seems to be a characteristic of a particular kind of sources. The Fig. 4b shows a similar analysis on the subsample identified with stars (158 X ray sources) confirming the behavior of Fig. 4a. In particular the group of stars for which the null hypothesis is rejected at high confidence level (>99%) are usually optical variable stars as young stars, T Tauri, RS CVns, flare stars, OB stars, etc.
Fig. 4 - (a-left) Integral distribution of fraction of X ray sources for which we can reject the null hypothesis of source constancy at given confidence level; (b-right) Similar plot as in (a) for the stellar subsample.

Acknowledgments

We would like to thank support from PSN-CNR and MPI.

References
