Galactic X-ray surveys: the role of small missions

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Abstract. Since young late-type stars are intense coronal emitters X-ray observations are becoming an election method for studying the properties of the young (age $< 10^9$ yr) stellar population in the Galaxy including the stellar birthrate, the determination of IMF and the changes of stellar coronae with age. After recalling some recent results I will discuss my view on the role of and the need for small dedicated missions to address scientific problems that will be largely uncovered by both CHANDRA and XMM and by observatory-class missions today conceived.

1. Stellar populations in the Galaxy

Surveys based on the ROSAT All Sky Survey (RASS) (Motch et al. 1997; Zickgraf et al. 1998) and on deeper, smaller area pointed survey, such as the Galactic Plane Survey (Pye et al. 1997) have given important contributions to the study of the stellar content of the Galaxy. We have a clear evidence of a Pleiades-age stellar population with a scale height (around the Galactic plane) of 100 pc or less that was already seen, at lower statistical significance, through the analysis of the *Einstein* EMSS (Micela et al. 1993, Favata et al. 1993, Sciortino et al. 1995). There is also evidence of a lower density population of very young stars far from the cores of SFRs (Zickgraf et al. 1998; Covino et al. 1997). The last years have seen an intense debate on the widespread presence of this very young population and on its space density (Neuhäuser 1997 and references therein; Briceño et al. 1997; Favata et al. 1997). This debate has clearly demonstrated the importance of follow-up optical high-resolution spectroscopy program to properly assess the nature of detected stars. In this respect next generation multi-fiber high resolution instruments, such as the VLT-Flames+UVES and the MMT-Hectoechelle, will play a crucial role together with the investigation of new, promising, spectroscopic tracers of the very young stellar population (cf. Terranegra et al. 1999).

One of the most interesting results of X-ray surveys has been obtained by Guillout et al. (1998a) cross-correlating the RASS source list and the Tycho catalog. They have found a population of young active stars whose distribution is tilted with respect to the Galactic plane (cf. Fig. 1). Guillout et al. (1998b) have proposed a model in which this population is interpreted as the late-type stars of the Gould Belt (that indeed they better model as an inclined ellipsoidal disk-like structure). However more deeper X-ray and optical data on the far side

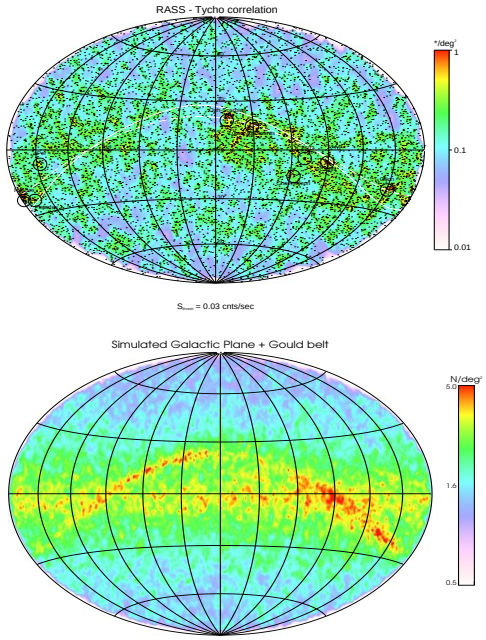

Figure 1. (upper) - The result of the Tycho-RASS correlation. Each black point indicates a successful match. Note the enhanced density around the Galactic plane due to the Pleiades-age population and the tilted excess in the 230°–330° b range. The smooth curve indicates the Gould Belt. (lower) A simulation of the spatial density of the X-ray–optical matches from a 5 times deeper survey than the RASS and an optical catalog complete to $m_V = 15$ for stellar populations whose spatial distributions follow the model of Guillout et al. (1998b)

of the disk (at $l \sim 90°$) are need to test the reality of the proposed structure. This is illustrated in Fig. 1 (courtesy of P. Guillout) showing the results of the RASS-Tycho correlation and the simulated result of a 5 times deeper X-ray survey than the RASS. As discussed extensively below, this is the kind of problem for which both CHANDRA and XMM will be of limited help.

2. X-ray coronal spectroscopy

Taking advantage of the low (PSPC), medium (ASCA, SAX) and few high (EUVE) resolution coronal spectra several groups have started sophisticated modeling of stellar coronae to derive the Differential Emission Measure (DEM, cf. Dupree 1996), an important tracer of the coronal heating mechanisms, and of the thermal and physical structure of the corona (such as typical loop lengths, cf. Maggio & Peres 1997, Sciortino et al. 1998) and have started to investigate more complex questions such as the ageing of the coronal spectra (Güdel et al. 1997), or the determination of coronal abundances (cf. Drake 1996 for a recent review) and their comparison with photospheric ones (Ottmann et al. 1998). Many studies to date are clearly hampered by the counting statistics (i.e. by

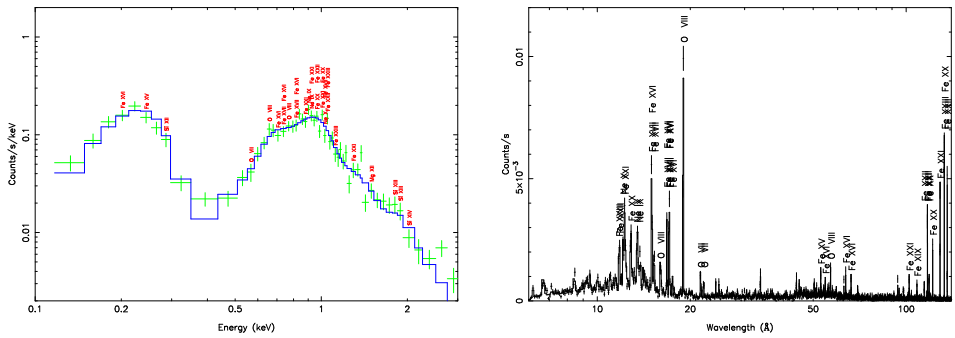

Figure 2. (left) - The SAX LECS spectrum of AD Leo, a nearby dMe star, and the most intense X-ray emitter in its class, collected in about 20 ksec with indicated the position of the more prominent Fe lines predicted by the best-fit model (cf. Sciortino et al. 1998). (right) - The simulated CHANDRA LETG spectrum of AD Leo in a 100 ksec observation for the same best-fit model of the right panel. The about 1000 spectral resolution will disclose for the first time the richness of the coronal spectrum and of its physics.

the limited collecting area) and poor resolution (due to detector intrinsic physical limit) of available spectra. The limited spectral resolution usually achieved (cf. Fig 2) prevents any detailed analysis of the rich forest of lines that the best-fit model predicts. It is worth to stress that any improvement in spectral resolution needs to be accompanied by a substantial increase in collecting area at level even higher than the XMM one (cf. Fig. 4) to prevent being photon starved even for a relatively strong X-ray source such as AD Leo ($f_X \sim 3\ 10^{-11}$ erg/s/cm^2). With the CHANDRA and XMM medium-resolution ($\sim$ 70 eV) CCD-based detectors and, especially, with the high-resolution (grating-based) spectrographs our capability to investigate the coronal physics in stars different from the Sun will make a big leap forward. This is well illustrated by the predicted CHANDRA-LETG AD Leo spectrum collected in a 100 ks observation (cf. Fig. 2). Even if the efficiency of a grating spectrograph (usually in the 20-30% range) drastically reduces the effective collecting area of CHANDRA (cf. Fig. 4) and requires long integration time, yet the richness of the spectrum is worth the price! High resolution spectra will allow us to derive in a more reliable way coronal abundances without many of the difficulties/drawbacks of current, and quite controversial, determinations based on low-medium resolution spectra.

Measurements of the individual intensities of helioid triplet lines will make it possible the (almost) model independent determination of coronal densities at the temperature of formation of various triplets. Indeed, the ratio of the intercombination and forbidden lines furnishes a quantitative diagnostic of the coronal density. While being a very exciting possibility, I want to stress that such an analysis will only be possible for the more intense (and usually nearby) coronal sources. Even with the large collecting area of the RGS onboard XMM it will be essentially impossible to attempt such an analysis for young Pleiades stars since the required observation times will be prohibitively too long!

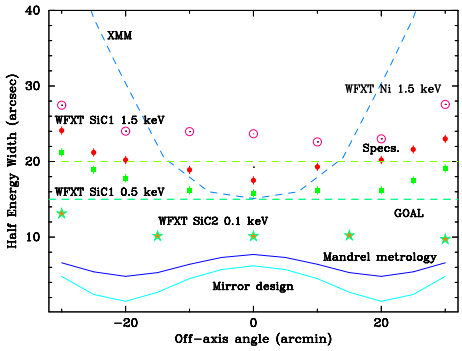

Figure 3. The measured PSF HEW of a recently built silicon-carbide (SiC2) WFXT mirror of 60 cm diameter compared with the PSF HEW of the XMM mirror and the specification and goal of the WAXS/WFXT proposed mission. The improvement in the replica process adopted for the SiC2 mirror has already allowed to meet the very stringent mission goal of $\sim$ 12" PSF HEW over 1° diameter field-of-view.

3. The role of small missions

I am deeply convinced that while it is imperative for X-ray astronomers to work for the next-generation observatory class missions like the proposed Constellation-X (NASA) and XEUS (ESA), still, given their long-term development time and their small field-of-view ($\sim$ 10 arcmin), there is plenty of room for small dedicated missions to address scientific questions that the future observatory-class missions will not address, or to timely demonstrate the effectiveness of crucial developments in detector and mirror technologies.

3.1. Wide Field X-ray Telescope (WFXT) and galactic surveys

Notwithstanding the tremendous impact we expect from the new exciting CHANDRA and XMM observations, it is not a difficult prediction that there are important questions that will only marginally (if any) address. Limiting ourselves to the case of stellar physics, it should be evident that CHANDRA, XMM or any observatory-class mission will hardly address the problem of the large scale distribution of young stellar populations in the Galaxy, since it will be impossible to devote enough time for such a demanding program!

Moreover such an investigation requires the capability to obtain high-quality identifications, largely based on statistical criteria, such as spatial matching and f_X/f_V ratio, in order to make the problem manageable. This can be possible **only** if the positional uncertainties of the X-ray sources can be kept within few arcsecs over the entire explored areas. This can hardly be possible over the entire field-of-view either with CHANDRA or XMM since both are based on Wolter-I optical design, whose image quality degrades rapidly with off-axis angle. A different optical design is required, such as the one recently adopted and proven to work by O. Citterio and his group at Oss. Astr. di Brera/Merate (cf. Citterio et al. 1998). The image quality (as measured by the PSF HEW) remains

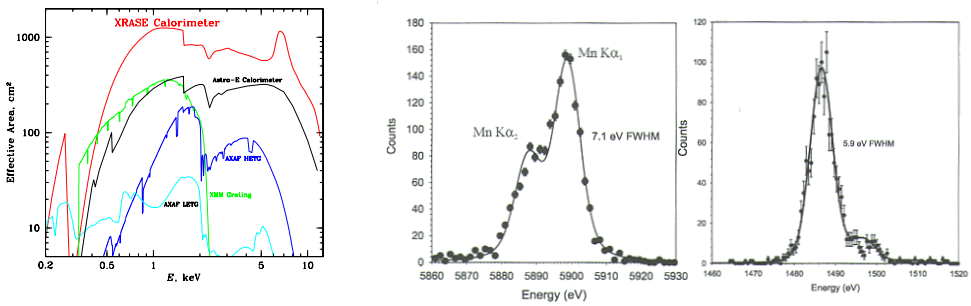

Figure 4. (left) The effective area of the proposed XRASE and of CHANDRA, XMM and ASTRO-E high resolution spectrographs. The innovative calorimeter and mirror design allow XRASE to outperform all other missions. (right) Laboratory measurements of X-ray lines with XRASE-like calorimeters showing that a resolution better than 10 eV has already been achieved.

virtually constant at $\sim$ 12" across a 1° field of view, allowing the realization of a Wide Field X-ray Telescope (WFXT, cf. Fig. 3). Such a telescope has been recently proposed as the core element of the Wide Area X-ray Survey mission (WAXS, Chincarini et al. 1999), proposed to the ASI small mission program, by an international collaboration including italian groups, the HEAD at SAO (Cambridge, USA), the X-ray Astronomy Group (Leicester, UK) and the MPE (Garching, FRG). The phase-A study has demonstrated the scientific validity of the mission and its feasibility in a 2 year time-frame. WAXS/WFXT is, in my opinion, a milestone for X-ray astronomy.

3.2. XRASE and high-resolution coronal spectroscopy

High resolution spectroscopy of young stars (the nearest ones being the Pleiades members) detected in the RASS (i.e. with a limiting flux of $few \times 10^{-13}$ erg sec^{-1} cm^{-2}, $\sim$ 100 times fainter than AD Leo) will be impossible with CHANDRA, XMM and ASTRO-E [1]. However such an observation is today achievable as illustrated in the XRASE proposal by Silver et al. (1998) submitted to the NASA Midex program. The new-technology ultra-light multilayer-coated mirrors with angular resolution of $\leq$ 1 arcmin make it possible to obtain large collecting area (cf. Fig. 4) even above the $\sim$ 4 keV region where traditional mirrors have a lower efficiency. The adoption as an imaging-spectrograph of a matrix of calorimeters will make it possible to reach the few eV resolution without the large loss of efficiency of the gratings. I want to stress that *such a matrix of calorimeters can be built today* and its elements (individual calorimeter) have the required energy resolution (cf. Fig. 4) for allowing the direct determination of coronal density (or to address any other physical problem that requires few eV resolution).

[1] The calorimeter on board Astro-E (to be launched on year 2000) **will not** have the energy resolution to be competitive with the grating spectrometers of CHANDRA or XMM.

Acknowledgments. I wish to thank my colleagues at Oss. Astronomico di Palermo (M. Barbera, F. Damiani, G. Micela, R. Pallavicini, G. Peres, A. Maggio) for many enlightening discussions and for some of the unpublished material. I wish to thank the WAXS/WFXT team at Oss. Astr. di Brera and the XRASE team at SAO for their hard work in the small mission field. This work has been partially supported by MURST and ASI.

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