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X-Ray Surveys and Young Stellar Population: Constraints on Stellar Birthrate in the Solar Neighborhood

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Abstract.
The analysis of the stellar content of X-ray surveys gives us a powerful tool to explore the properties of young stellar populations in the solar neighborhood. In particular we discuss the capabilities of X-ray observations in contraining the stellar birthrate in the last billion years. Results of the pointed Rosat Galactic Plane Survey point towards a density of young stars in the solar neighborhood higher than previously thought. Moderately deep, high latitude X-ray surveys, will allow us to constrain the scale heights of the youngest populations and to assess the occurrency of a recent episode of stellar formation in the solar neighborhood.

1. Introduction

X-ray surveys are very effective to study young stars, essentially because the X-ray luminosity decreases up to 3 orders of magnitude during the main sequence stellar life while the optical properties remain substantially unchanged. In X-ray we can observe young stars at distances much larger than old stars, so young stars are oversampled in X-ray observations and dominate these samples. We can take advantage of this, and X-ray surveys have been extensively used to derive global properties of young stellar populations.

2. X-Count, a model of the stellar X-ray component of the Galaxy

In order to estimate the population parameters of active stars we have built a model (X-Count) able to predict the number of X-ray detected normal stars and their population properties (Favata et al. 1992). Main ingredients of a such a model are the stellar spatial distribution, a model of interstellar gas, important to take into account the interstellar absorption of soft X-ray photons, and the stellar X-ray luminosity functions. Originally X-Count was built to be compared with *Einstein* and ROSAT observations. Given the limited sensitivity of these observations and the low density of thick disk and halo stars in the solar neighborhood, we had modelled only the thin disk component.

To model the spatial distribution of this component we have used a set of exponential disks similar to those of the Bahcall & Soneira model (Bahcall & Soneira 1984). In our implementation an important difference with respect to the original Bahcall & Soneira distribution is present, since the scale heights are functions of the stellar mass (as in the original model) **and** of the stellar age. This dependence is very important for predictions in X-ray domain, since X-ray luminosity is strongly dependent on age, but, as we have checked, has little effect on optical counts (Micela, Sciortino & Favata 1993).

In the last version of the model we can, alternatively, use the most recent distribution of dM stars derived by Gould from HST observations (Gould, Bahcall & Soneira 1997).

Since the dependence of L_x on age is only coarsely known, we have subdivided the stars in three different ranges of age, and for each of them we have assumed a scale height and an X-ray luminosity function, as follows:

- Young stars: $10^7 <$ Age $< 10^8$. Scale height of 120 pc, X-ray luminosity functions of the Pleiades (Micela et al. 1990,1996,1999)
- Intermediate aged stars: $10^8 <$ Age $< 10^9$. Scale height of 200 pc, X-ray luminosity functions of the Hyades (Micela et al. 1988)
- Old-disk stars: $10^9 <$ Age $< 10^{10}$. Scale height of 400 pc, X-ray luminosity functions of nearby old stars (Schmitt et al. 1985, Maggio et al. 1987, Barbera et al. 1993)

It is worthwhile to note that the major contributions to X-ray counts come from the high luminosity tails of X-ray luminosity functions, since the more luminous stars are detectable in much larger volume. The tails are typically due to few stars, hence, their uncertainty is the major source of uncertainty in predictions.

3. Constraints on stellar birthrate

Comparisons of X-ray selected stars and models can put contraints on the stellar birthrate in the solar neighborhood in the last billion year (Micela, Sciortino, Favata 1993, Guillout et al. 1996).

In Figure 1 we plot the expected log N−log S, at high galactic latitude (solid line) obtained with X-Count assuming constant stellar birthrate. The other lines indicate the contribution to the log N−log S of the stars for each age range. At high fluxes the youngest stars dominate, at intermediate fluxes we have already detected essentially all the young stars, and the intermediate stars dominate, at low fluxes we have already reached their scale height and we will have additional contribution only from old stars. Of course at a given flux the relative contribution of the various populations depends on stellar birthrate, and the global shape and normalization change as a consequence. Figure 2 shows the log N−log S expected assuming four different birthrates, the highest line corresponds to an increase of the stellar birthrate (SBR), the second to a constant stellar birthrate and the remaining to a slow and rapid decreases of SBR, respectively. Points are derived from the *Extended Medium Sensititvity*

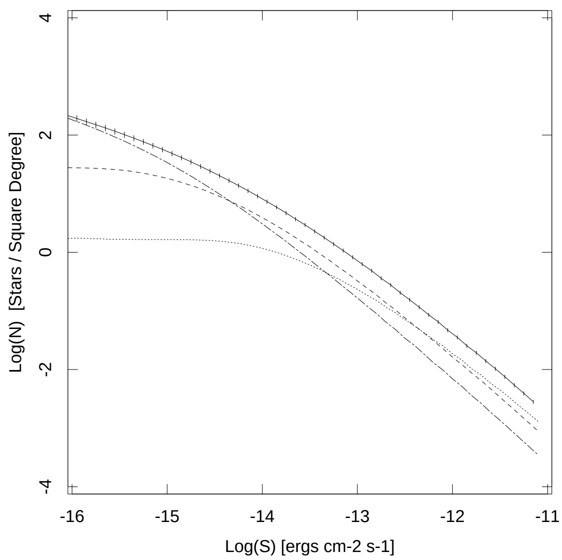

Figure 1. Expected log N - log S, at high galactic latitude (solid line) obtained with X-Count, assuming a constant stellar birthrate. Vertical segments are the error bars due to the uncertainties on X-ray luminosity functions. The contributions of young stars (dotted line), intermediate age stars (dashed line), and old stars (dotted-dashed line) are shown separately. (Adapted from Micela et al. 1993)

Survey (EMSS, Gioia et al. 1990). The comparison between data points and predictions seems to rule out models with a decreased birthrate. Note that the points at high fluxes are below any predictions since the EMSS is biased against high flux sources.

Important constraints can be derived from observations on the Galactic Plane, where observations will be affected only by the density of active stars, and not by the scale height of the population. For this purpose Morley et al. (2001) have analyzed the central regions of 9 moderately deep ROSAT/PSPC fields, at galactic latitude within 0.3° from the plane, corresponding at 1 kpc to 5 pc, implying that we are really observing on the Plane.

The total sky coverage is small, only 2.5 sq. degrees but the sensitivity is ten times deeper than other galactic plane surveys (Hertz & Grindlay 1988, Motch et al. 1991). In total 93 sources have been detected. A statistical identification procedure, based on the f_x/f_v ratio and optical magnitude and color of possible counterparts, classifies most of the sources as coronal sources. The observed log N - log S has been compared with the predictions of the X-Count model, and of the Besancon model (Guillout et al. 1996). This latter model is conceptually similar to X-Count but with a different stellar spatial distribution resulting in a smaller scale height than in the case of X-Count.

The ROSAT pointed Galactic Plane Survey observations are consistent with a value of density of young stars on the Plane higher than commonly thought, but cannot discriminate among a) models with large scale height and enhanced star formation rate in the last billion year or b) models with small scale height and constant stellar birthrate.

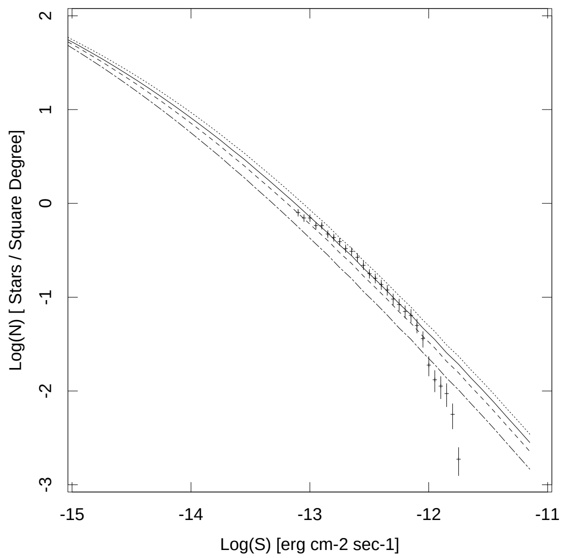

Figure 2. Log(N)-Log(S) in the 0.16-4.0 keV band predicted in the direction $l = 90^\circ$ assuming constant birthrate (solid line), slowly decreasing birthrate (dashed line), slowly increasing birthrate (dotted line), and rapidly decreasing birthrate (short-dashed line). Vertical segments are the experimental points (with error bars) obtained from the EMSS. (Adapted from Micela et al. 1993)

4. The future

Chandra and XMM/Newton observations will allow us to better constrain SBR in the solar neighborhood. In particular the XMM Galactic Plane Survey will allow us to explore larger distances and to probe different directions of the Plane and the XMM and Chandra Deep High latitude surveys will allow us to discriminate between the two possibilities described in the previous section. Indeed the two scenarios produce significant different predictions at high latitudes. In the case of small scale height and constant stellar birthrate we will predict a smaller number of sources, while in the case of large scale height and enhanced stellar formation we will detect more stars. Furthermore the age distribution of the two samples will be very different with much more young and intermediate age stars in the second case.

The present version of our model does not model thick disk or halo stars, since up to now, the coronal sources belonging to these populations, are negligible. It is possible that with the surveys of XMM/NEWTON and CHANDRA we need to include their effects. In principle is easy to introduce these new components in the model.

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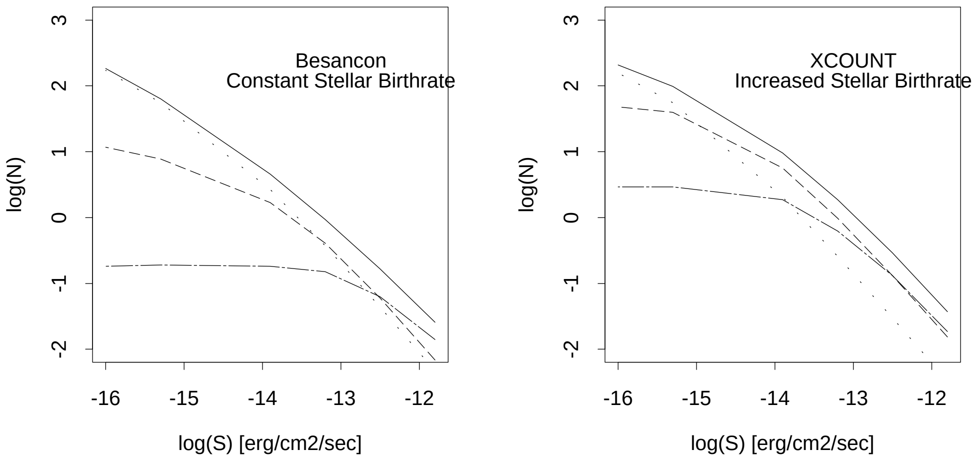

Figure 3. Log N - Log S predicted at high galactic latitude (solid line), with the contribution of young (dotted-dashed line), intermediate (dashed line), old stars (dotted line) for the Besancon model (on the left) with a constant stellar birthrate and small scale height, and for X-Count model (on the right) computed with an enhanced SBR in the last billion years and a large scale height

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