X-ray emission and variability of young, nearby stars

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Abstract. One of the most prominent properties of young stars is strong and variable X-ray emission. The All-Sky Survey performed by ROSAT and the new high sensitivity and high spectral resolution X-ray mission XMM provide complementary information about stellar X-ray sources. While the spatial completeness of the survey is indispensable for the identification of related groups of stars, detailed variability studies and spectroscopic analysis for individual objects are possible with the improved effective area, gratings and CCD chips onboard XMM.

1. Introduction

X-ray emission has played a major role in the recent identification of several groups of young, nearby stars. The ROSAT All-Sky Survey (RASS) is due to its spatial completeness an important tool for discovering stellar associations and investigating their X-ray properties. However, it has comparatively low sensitivity and poor temporal coverage, and is therefore of limited use for variability studies. The situation is greatly improved by the new generation of X-ray observatories, e.g. for coronal X-ray sources XMM has about an order of magnitude higher sensitivity than the RASS and provides much longer exposure times allowing continuous monitoring for more than 40 h.

In this contribution we aim at demonstrating the capabilities of both the RASS by comparing X-ray luminosity functions (XLF) of different young stellar associations, and XMM by discussing one young very nearby star in detail, GJ 182.

2. The Tucana Region and Other Nearby Stellar Associations

The Tucana association (= TucA; Zuckerman & Webb 2000) is one of several recently identified groups of young stars, which include the TWHya association (TWA), the η Chamaeleontis cluster (η Cha), and the Horologium association (HorA). Guenther et al. (2001) and more recently Zuckerman et al. (2001) suggested that HorA and TucA form a common group.

We have performed a detailed study of the X-ray emission from the stars in TucA making use of the RASS (Stelzer & Neuhäuser 2000), and have presented the first X-ray luminosity functions (XLF) for TucA and TWA. Here, we extend our investigation to the stars from η Cha (Mamajek et al. 1999) and...
Figure 1. XLF of nearby young stellar associations. For comparison the XLF of the Taurus-Auriga star forming region, the IC 2602 cluster and the Pleiades are shown. The numbers given in the right of the graph are the mean X-ray luminosities computed with ASURV (Feigelson & Nelson 1985) taking account of upper limits for non-detections.

Figure 2. X-ray luminosity $L_x$ versus spectral type. Within the group of stars with significant convection zones (i.e. spectral types G and later) $L_x$ declines as the stars become cooler. As expected most A- and B-type stars are undetected in X-rays.
HorA (Torres et al. 2000). The XLF for all four groups are presented in Fig. 1. The luminosity distributions show significant overlap, indicating that the average level of X-ray emission is similar for all groups. The comparison with the XLF from the pre-main sequence stars in the Taurus-Auriga region, the young cluster IC2602, and the Pleiades shows that the above mentioned four young associations have X-ray luminosities comparable to pre-main sequence (PMS) stars and are significantly X-ray brighter than the 108 year-old Pleiades. This can be taken as supporting evidence for their youth. A closer inspection of the XLF reveals the following characteristics:

The HorA sample shows the highest X-ray luminosities. This presumably demonstrates a selection bias: HorA was found by follow-up observations of RASS sources, i.e. all members of HorA known so far are X-ray emitters. X-ray fainter or quiet members in this region are likely to exist, but have yet to be discovered (see e.g. the contribution by C. Torres in these proceedings). The η Cha group has also been discovered by their X-ray emission, however, on basis of the more sensitive pointed observations by the ROSAT HRI. TucA was identified as a group of stars with common proper motion and distance, and includes also objects not detected in X-rays, i.e. the sample is likely to be more complete. While several TWA members were also discovered in X-ray selected samples from the RASS, all the pre-ROSAT known TTS in TWA were discovered in optical and IR observations, hence there is no strong X-ray bias in TWA. The XLF of the TWA stars is steeper than all other distributions. This could be due to the very narrow spectral type distribution of the known members of this association.

The relation between X-ray emission and spectral type is shown in Fig. 2. Dynamo-driven magnetic activity sets in around spectral type ∼F5, as the stars start to have significant convective envelopes. Therefore, only stars with spectral type G and later have been considered in the XLF presented in Fig. 1. A substantial number of members of TucA are A- or B-type stars, and not detected in X-rays in agreement with theoretical expectations. Among the late-type stars a clear trend towards declining $L_x$ is observed as stars become redder presumably as a result of smaller (radiating) surface area.

3. GJ 182

GJ 182 is a young field star (Gliese 1969) located at a Hipparcos distance of 26.7 pc, and stands out as particularly Lithium rich ($W_{Li} \sim 270$ mÅ; Favata et al. 1997) for its evolutionary age inferred from standard theory (∼40 Myrs; Favata et al. 1998). It is believed to be one of the most active, nearby stars. Frequent flares in the U-Band have been reported (de la Reza et al. 1981), and the $\lg (L_x/L_{bol})$ ratio is close to the canonical saturation limit for late-type magnetically active stars ($\lg (L_x/L_{bol}) = -3.15$; Hünsch et al. 1998).

In September 2000 GJ 182 was observed with XMM. The lightcurves in different X-ray energy bands obtained from this ∼17 ksec observation are shown in Fig. 3. Low level variability is observed below ∼4 keV, above this energy the source emits almost no X-rays. This is also evident from the EPIC-pn CCD spectrum shown in Fig. 4. A 3-temperature model for thermal emission from a hot plasma with electron density fixed at $10^{10}$ cm$^{-3}$ (solid line in Fig. 4) provides
a good description of the data ($\chi^2_{\text{red}} = 1.01$, 280 degrees of freedom). The fit is acceptable only if the elemental abundances are allowed to vary (see Table 1 for a summary of the spectral parameters). The two lower temperatures are comparable to results from the ROSAT PSPC spectrum during the quiescent state, which due to the instruments’ restriction to lower energies required only two spectral components. During a flare observed by ROSAT the higher temperature of the 2-T model increased as a result of coronal heating, while the lower temperature remained unaffected. This indicates the presence of a permanent level of quiescent emission, as has been observed before on other flaring stars (Stelzer & Huellamo 2000).

### Table 1. Spectral parameters for GJ 182 derived from ROSAT PSPC and XMM EPIC-pn observations. The observation ID is given in brackets.

| ROSAT PSPC (200517p/p-1) | XMM EPIC-pn (0112880401) |
|--------------------------|--------------------------|
| **Flare** | **Quiescence** | **Flare** | **Quiescence** |
| $kT_1 = 0.10^{+0.04}_{-0.03}$ | $kT_1 = 0.10^{+0.19}_{-0.34}$ | $kT_1 = 0.21^{+0.05}_{-0.08}$ | O $0.48^{+0.31}_{-0.12}$ |
| $kT_2 = 0.68^{+0.07}_{-0.05}$ | $kT_2 = 0.88^{+0.98}_{-0.25}$ | $kT_2 = 0.66^{+0.03}_{-0.03}$ | Ne $1.06^{+0.29}_{-0.26}$ |
| | | $kT_3 = 1.93^{+0.48}_{-0.29}$ | Mg $0.33^{+0.14}_{-0.14}$ |
| | | | Si $0.80^{+0.52}_{-0.41}$ |
| | | | S $0.80^{+0.52}_{-0.41}$ |
| | | | Fe $0.22^{+0.07}_{-0.03}$ |

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X-ray emission and variability of young, nearby stars

Figure 3. Smoothed XMM EPIC-pn lightcurves for GJ 182 in different energy bands. The vertical lines at the left side of the plots are the mean errors in the respective energy band.

Figure 4. XMM EPIC-pn count rate spectrum of GJ182, 3-temperature best fit model, and residuals.