THE XMM-NEWTON SURVEY OF THE TAURUS MOLECULAR CLOUD: ACCRETION, JETS, AND FLUORESCENCE

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ABSTRACT

The Taurus Molecular Cloud (TMC) is one of the best studied star forming regions. It is close (140 pc) and represents the mode of isolated, non-clustered star formation. XMM-Newton has surveyed the richer 5 square degrees of the TMC in X-rays and has obtained high-quality photometric and spectroscopic data of young stars and brown dwarfs in their early stages of formation. We present results of the X-ray Emission Survey of TMC (XEST) on the following topics: i) Accretion. The origin of X-rays in young, accreting stars is controversial, as accretion appears to be the dominant emission mechanism in some classical T Tauri stars, whereas magnetic activity is the preferred explanation for others. The TMC contains several accreting stars whose spectra help us understand the importance of accretion for the production of X-rays. ii) Jets. Young, accreting stars display jets detected in the optical, near-infrared, and radio domains. There is now evidence that jets are also detected in X-rays in some TMC targets. iii) Fluorescence. The detection of an emission feature at 6.4 keV indicates that fluorescence of Fe in a cool environment, e.g., the accretion disk, takes place due to photoionization by hard X-rays or collisions with electron beams. We have possibly detected Fe K-shell fluorescent emission.

Key words: Star formation; X-rays; Jets; Accretion; Fluorescence.

A detailed discussion is available in the Güdel et al. proceedings paper (this volume).

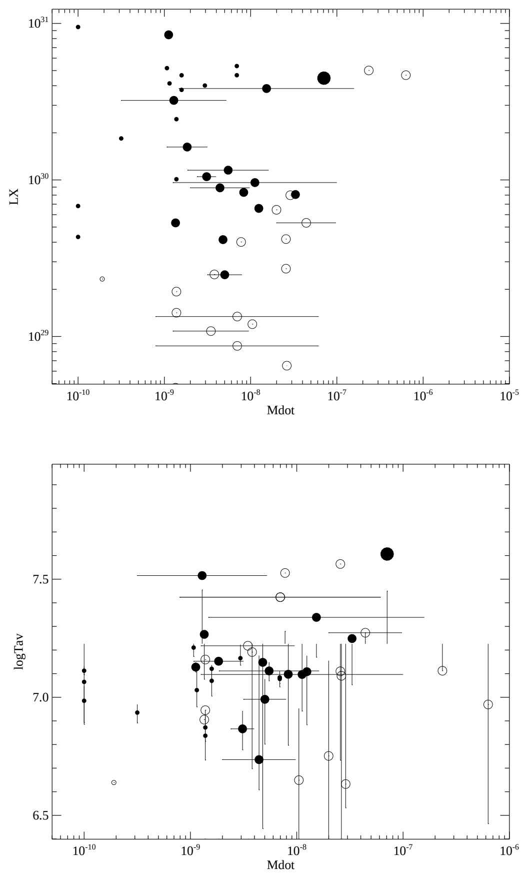

Figure 1. Plasma temperature (top), and $L_{\mathrm{X}}/L_{\mathrm{bol}}$ ratio (bottom) versus the mass accretion rate. Large bullets = Class I; Medium bullets = Class II; Small bullets = Class III. Empty bullets: based on spectral fits for spectra of < 400 counts, and thus the resulting parameters are less reliable. No trend can be found for the average plasma temperature, or the $L_{\mathrm{X}}/L_{\mathrm{bol}}$ ratio as a function of the mass accretion rate, indicating that accretion plays little role in the production of X-rays in young stars in TMC.

ACKNOWLEDGMENTS

We acknowledge support from NASA grant NNG05GF92G and from grant 20-66875.01 from the Swiss National Science Foundation. We thank the International Space Science Institute in Bern for their support to organize team meetings. Based on observations obtained with XMM-Newton, an ESA science

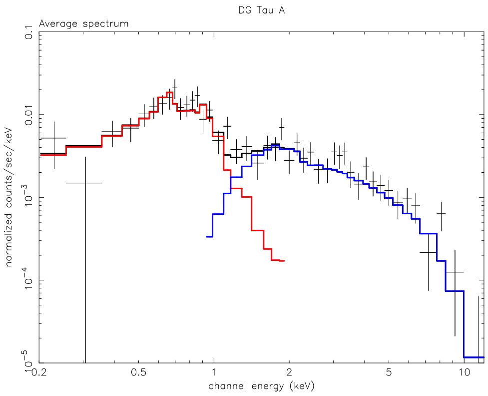

Figure 2. XMM-Newton EPIC pn spectra of DG Tau A as black crosses (GV Tau A and DP Tau also show similar spectra). Two components with different $N_{\rm H}$ are required and shown as red (soft) and blue (hard) histograms. The soft component is probably due to shocks in the fast inner jet observed in the stars, as postulated by Güdel et al. (2005) who observed a similar soft component in DG Tau A and along the optical jet with Chandra.

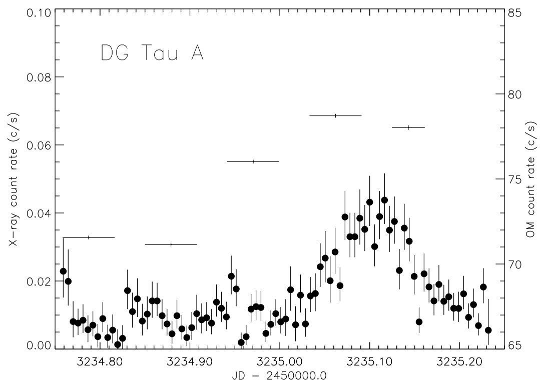

Figure 3. Full-band X-ray light curve (dots) and OM U-band light curve (crosses). The peak of optical light curve precedes the peak of the X-ray light curve, a signature of the Neupert effect and indicative of chromospheric evaporation (Neupert, 1969; Güdel et al., 2002a,b)

mission with instruments and contributions directly funded by ESA Member States and NASA.

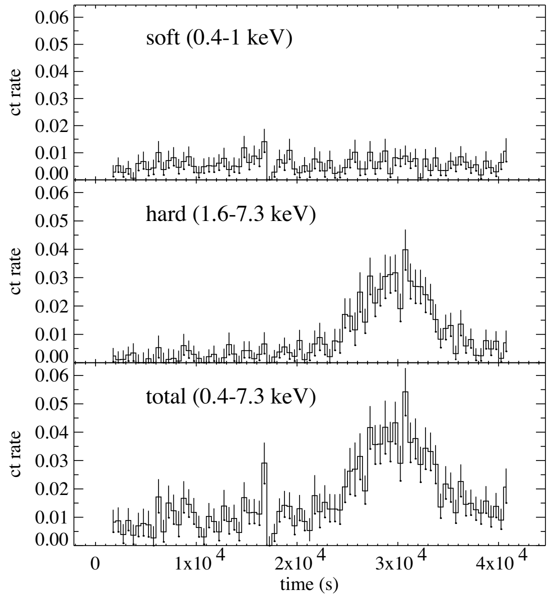

Figure 4. X-ray light curve of DG Tau A, binned to 500s. From top to bottom: Soft photons 0.4-1.0 keV; Hard photons, 1.6-7.3 keV; full band, 0.4-7.3 keV; hardness ration (hard/soft). The hard component only is X-ray variable.

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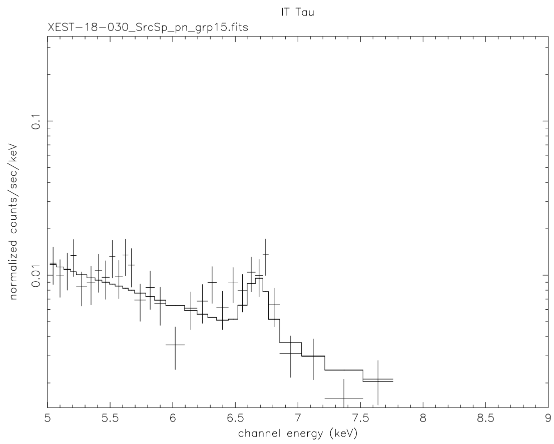

Figure 5. Zoom-in of X-ray EPIC pn spectrum of IT Tau. The XMM-Newton EPIC pn spectra of the Class II stars FS Tau and IT Tau (both unresolved Class II binaries) show tentative evidence of flux excess at 6.4 keV, possibly as a sign of fluorescent emission of cold Fe because of stellar X-ray irradiation onto an accretion disk. Similar features were observed in young stars (Imanishi et al., 2001; Favata et al., 2005; Tsujimoto et al., 2005).