X-RAY EMISSION FROM THE YOUNG BROWN DWARFS OF THE TAURUS MOLECULAR CLOUD

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ABSTRACT

The X-ray Emission Survey of the Taurus Molecular Cloud (XEST) is an exceptionally large project to systematically investigate the high-energy properties of young stellar objects in this nearest star-forming region. It is accompanied by optical and near-infrared surveys of the same area. When *XMM-Newton* archival observations are added, the total X-ray exposure time is more than 200 hours shared among 25 pointings. In particular the surveyed areas, combined with two *Chandra* archival observations, allow us to study the X-ray emission of 19 young bona fide brown dwarfs (BDs) of the Taurus Molecular Cloud (TMC). We report here the properties of the X-ray emission of these young BDs. We detected half of this substellar sample in X-rays. Comparison with the properties of the X-ray emission from low-mass stars will allow us to investigate changes in the magnetic activity around the stellar/substellar boundary.

Key words: Taurus dark cloud; Brown dwarfs; X-rays.

Fig. 1 shows the TMC area surveyed with the XEST, which allows us to study the X-ray emission of 19 young *bona fide* BDs on the 32 BDs known in the TMC (Luhman 2000; Briceño et al. 2002; Luhman 2004; Guieu et al. 2005). The Hydrogen burning limit ($M_\star \sim 0.08\,M_\odot$) corresponds in the TMC to spectral type M6.25 or later (Fig. 2). We detected 10 young *bona fide* BDs in X-rays; the detection rate is hence 53%. Only 2 TMC BDs were previously detected in X-rays by *ROSAT*: CFHT-BD-Tau 4=HCl 2 NW-7a (Briceño et al. 1999), and MHO-4=RX 15 (Carkner et al. 1996). We detected an X-ray impulsive flare from CFHT-BD-Tau 4 (Fig. 3). The Optical Monitor detected a BD –not detected in X-rays– displaying during ~7 hrs an increase of its brightness, corresponding to $\Delta U \sim -2$ mag (Fig. 3). This slower variability is likely associated with an accretion event. Assuming that the relation $\log L_{\rm acc} \sim \log L_{\rm U}$ observed for T Tauri stars (Gullbring et al. 1998) is also valid for BDs, this implies an increase by a factor of ~6 of its accretion rate.

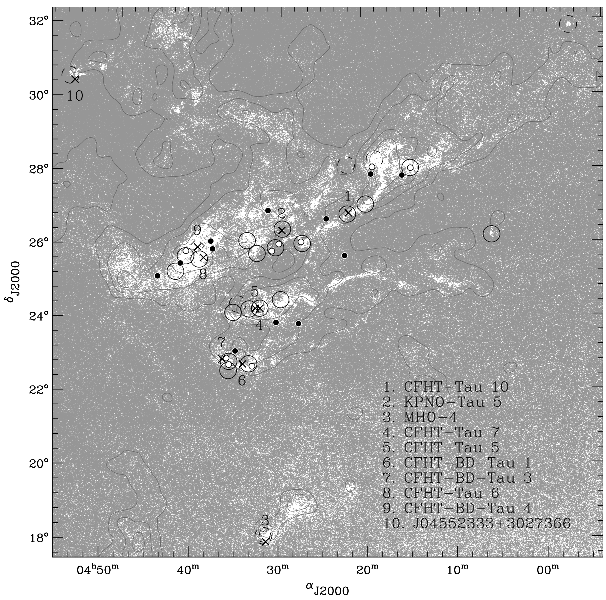

Figure 1. The XEST. Contours show the CO emission (Dame et al. 1987), overlaid on the USNO-A2 optical stars (Monet et al. 1998). XMM-Newton and Chandra field-of-views are indicated with circles and squares. Archival observations are plotted with dashed lines. Black dots show the 12 BDs not surveyed in X-rays. White dots show the 9 BDs not detected in X-rays. Blue crosses show the 10 BDs detected in X-rays.

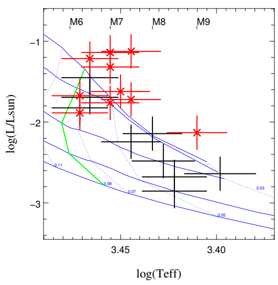

Figure 2. H.-R. diagram of XEST BDs (adapted from Guieu et al. 2005). X-ray detections are marked with 'X'. Isochrons (1, 3, 10, 30, and 100 Myrs) and mass pre-main sequence tracks (Baraffe et al. 2002) are shown for comparison.

We have in total 12 observations of the 10 BDs detected in the XEST, but spectral fitting can be performed for only 5 observations. For these fainter sources, we used

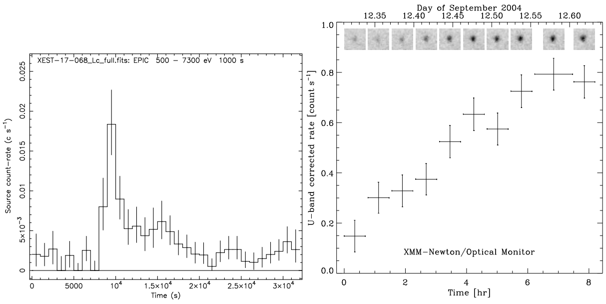

Figure 3. BD variability. Left: EPIC light curve of an impulsive X-ray flare from CFHT-BD-Tau 4. Right: Optical Monitor light curve showing in the U-band a slow rise, likely associated with an accretion event.

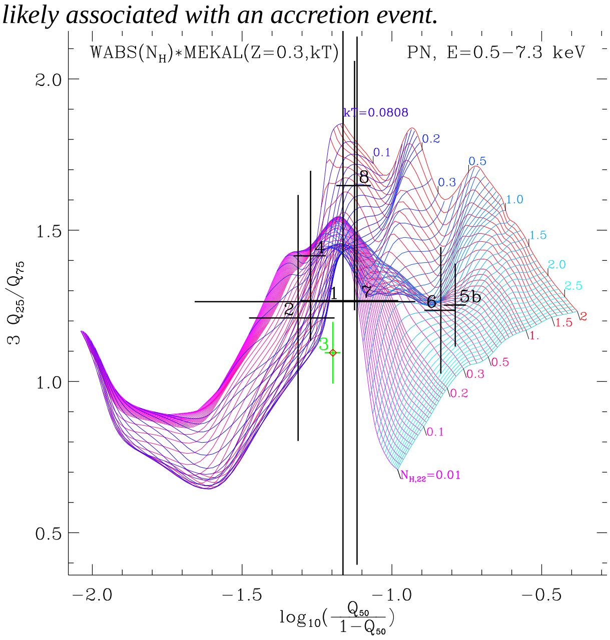

Figure 4. Quantile analysis and BD plasma parameters.

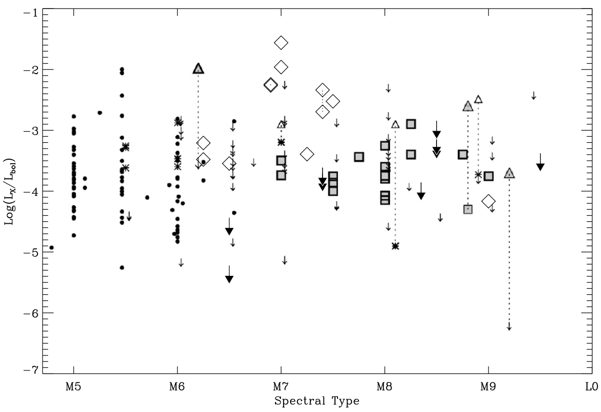

Figure 5. X-ray activity in the 0.5–8 keV energy range versus spectral type for M5 or later type objects (adapted from Preibisch et al. 2005). Late M field stars from Fleming et al. (1993) are shown as asterisks. The solid dots show T Tauri stars of the COUP. The previously X-ray detected BDs are shown by grey filled squares. Diamonds and thick arrows show the XEST BDs.

the quantile analysis method proposed by Hong et al. (2004), which is based on the median (50%) and quartile (25%, 75%) energies of the X-ray events and includes background substraction. We computed a grid of plasma models and plot a quantile-based X-ray color-color diagram for PN (Fig. 4), or MOS1+MOS2 for sources falling inside PN gaps. Grid lines indicate locii of iso-column density and iso-temperature, respectively. The 3 diamonds mark the X-ray colors corresponding to the plasma parameters obtained directly from spectral fitting. The X-ray colors of one source cannot be reproduced by a single plasma temperature; spectral fitting showed that a 2-temperature plasma is indeed needed. Optical extinctions were used for poorly constrained sources, and to disentangle double solutions. Then we computed from these plasma parameters the X-ray luminosities needed to reproduce the observed count rates. Fig. 5 shows a preliminary results of the study of the X-ray activity of the TMC BDs. They have essentially the same signatures of activity as older low-mass field stars and BDs with equivalent late-M spectral types. The implication is that the activity is mainly determined by the effective temperatures of the sources and not (so much) by their masses.

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