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X-ray emission from the young brown dwarfs of the Taurus Molecular Cloud

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Abstract. We surveyed with 15 *XMM-Newton* pointings, supplemented with one archival *Chandra* observation, 17 young brown dwarfs (BDs) with late M spectral types in the Taurus Molecular Cloud. Half of this sample (9 out of 17 BDs) is detected; 7 BDs are detected here for the first time in X-rays. We confirm several previous findings on BD X-ray activity: a log-log relation between X-ray and bolometric luminosity for stars and BDs detected in X-rays; a shallow log-log relation between X-ray fractional luminosity and mass; a log-log relation between X-ray fractional luminosity and effective temperature; a log-log relation between X-ray surface flux and effective temperature. We find no significant log-log correlation between the X-ray fractional luminosity and EW(Hα). Accreting and nonaccreting BDs have a similar X-ray fractional luminosity. The X-ray fractional luminosity declines from low-mass stars to M-type BDs and, as a sample, the BDs are less efficient X-ray emitters than low-mass stars. We thus conclude that while the BD atmospheres observed here are mostly warm enough to sustain coronal activity, a trend is seen that may indicate its gradual decline due to the drop in photospheric ionization degree.

Key words. Stars: low-mass, brown dwarfs – X-rays: stars – ISM: individual objects: the Taurus Molecular Cloud

1. Introduction

The *XMM-Newton Extended Survey of the Taurus Molecular Cloud* (XEST; Güdel et al. 2007) is a large program designed to investigate the X-ray properties of young stellar/substellar objects in the Taurus Molecular Cloud (TMC). In particular, the area surveyed by 15 (out of 27) *XMM-Newton* pointings, supplemented with one archival *Chandra* observation, allows us to study 17 young ($\sim$ 3 Myr) brown dwarfs (BDs) with late M spectral types (Fig. 1; Grosso et al. 2007).

2. X-ray properties of the XEST BDs

We detected half of this sample (9 out of 17 BDs); 7 BDs are detected here for the first time in X-rays. We detected mainly the BDs with

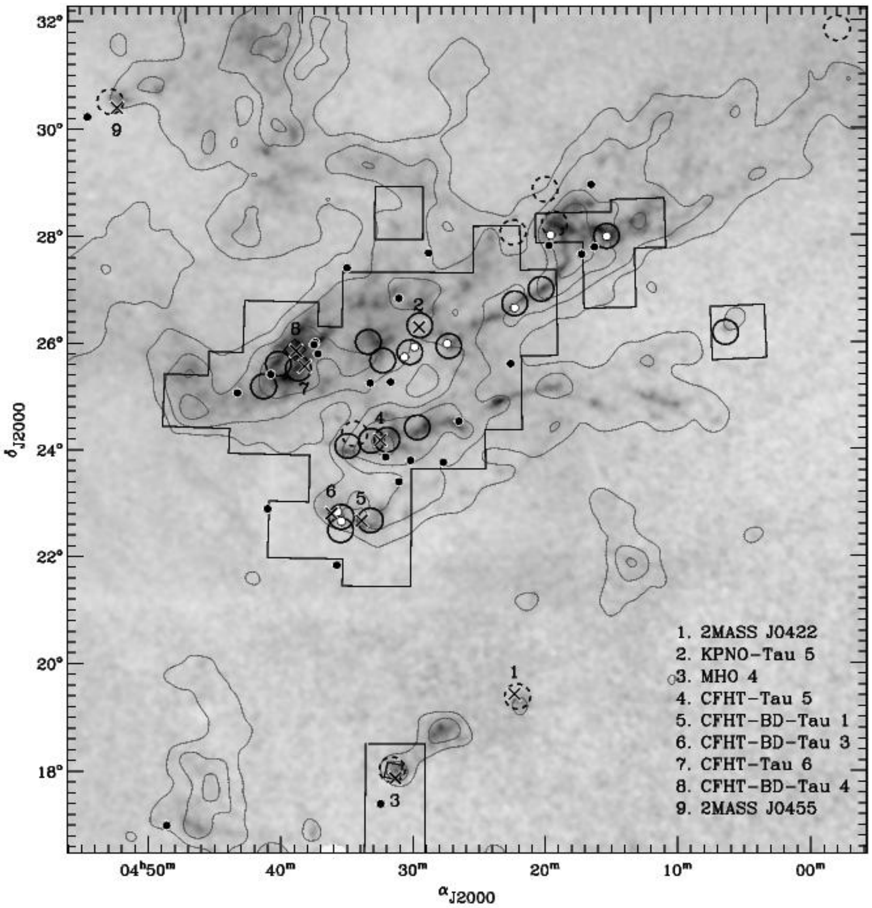

Fig. 1. The *XMM-Newton Extended Survey of the Taurus Molecular Cloud* (XEST). Contours show the ^{12}CO emission of the TMC (Dame et al. 1987), overlaid on a visual extinction map (Dobashi et al. 2005). The 27 *XMM-Newton* fields of view of the XEST are plotted with continuous and dashed (archive) circles. The two squares near labels 3 and 8 show the archival *Chandra* fields of view also used in this work. Other bold lines outline areas surveyed for BDs with the *CFHT* (Guieu et al. 2006). This region hosts 42 young BDs of the TMC (Briceño et al. 1998, 2002; Luhman 2000, 2004, 2006; Martín et al. 2001; Guieu et al. 2006). Black dots indicate the 25 BDs of this region not surveyed with the XEST. The 17 BDs included in the present X-ray study are plotted with white dots (8 BDs not detected) and crosses (9 BDs detected), with labels referring to BD names.

luminosities greater than ~0.01 $L_{\odot}$, i.e. with spectral type M8 or earlier.

Considering only the BDs and low-mass (proto)stars detected in the XEST (Fig. 2), we determined a log-log regression fit between X-ray and bolometric luminosity, which is consistent with $<\log(L_X/L_*)> = -3.5\pm0.4$. Including the 8 upper limits of undetected BDs, the median of $\log(L_X/L_*)$ is −4.0 for the XEST BDs. The X-ray fractional luminosity of XEST BDs is hence lower than the one of XEST low-mass stars. To investigate the relation between X-ray fractional luminosity and physical parameters when one moves from low-mass stars to the substellar regime, we focus on objects with spectral type M0 or later. A shallow relation is found between the X-ray fractional luminosity and the mass. We find a relation between

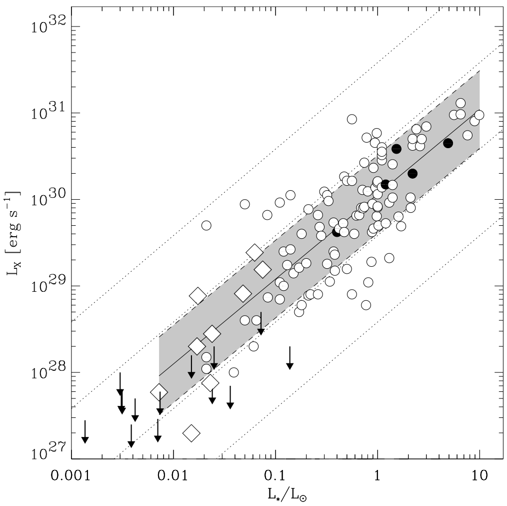

Fig. 2. X-ray luminosity vs. bolometric luminosity for the BDs (diamonds), low-mass stars and protostars (white and black dots) of the XEST (Güdel et al. 2007). There are only a few low-mass stars not detected in the XEST. The dotted lines indicate logarithmic X-ray fractional luminosities of -5, -4, -3, -2.

the X-ray fractional luminosity and the effective temperature of our sample ranging from ~3840 K to ~2500 K, implying a decrease of the X-ray fractional luminosity by a factor of about 3 from hot photospheres of solar-mass stars to cooler atmospheres of M9 BDs.

We compare the X-ray fractional luminosities of BDs with field stars with spectral type M5V or later, which also show $\log(L_X/L_*)$ as high as ~ -3 to ~ -4. Field stars with spectral type M7V and an age of 1 Gyr are twice as massive as a typical TMC BD with an M7 spectral type. Moreover, such very cool stars also have surface gravities about 40 times higher than in a typical young BD. This shows that the X-ray activity of BD coronae is not strongly dependent of the BD mass and surface gravity. The more fundamental relation that we found between X-ray activity and effective temperature agrees with the overall statistics for field dwarfs and BDs: of the 15 objects with spectral type M8.5 or later, only 4 have any detected quiescent X-ray emission; the rest are either not detected at all or (in 3 cases) detected only during strong flares.

We find no significant log-log correlation between the X-ray fractional luminosity and EW(Hα). Accreting and nonaccreting BDs in the TMC have a similar X-ray fractional luminosity.

3. Conclusion

We confirm that there is no dramatic change of the magnetic activity at the stellar/substellar boundary. Young BDs of spectral type M are sufficiently warm to sustain an active corona. The X-ray surface flux (i.e., the X-ray luminosity divided by the stellar surface) decreases with the effective temperature, but the young BDs in the TMC have on average an X-ray surface flux which is still 7 times higher than the one observed in the solar corona at the solar cycle maximum.

Deeper X-ray observations of the coolest M-type BDs in the TMC are needed to investigate a possible turn-over of the fractional X-ray luminosity of TMC BDs around spectral type M9.

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