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A *CHANDRA* OBSERVATION OF A TW HYDRAE ASSOCIATION BROWN DWARF

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ABSTRACT

We present *Chandra* observations of the young brown dwarf 2MASSW J1207334−393254, which is a probable member of the TW Hya association. Although this substellar object has strong Hα emission, it has no detected X-ray flux in a 50 ks ACIS-S observation. We place a conservative upper limit of 1.2×10^{26} ergs s^{-1} on its X-ray luminosity. We compare our M8 target to the similar mass object TWA 5B, which has weaker Hα emission but strong X-ray emission. We argue our results are consistent with the notion that 2MASSW J1207334−393254 is interacting with a disk.

Subject headings: open clusters and associations: individual (TW Hydrae) — stars: activity — stars: low-mass, brown dwarfs

1. INTRODUCTION

Brown dwarfs have proven to show a variety of phenomena that can be attributed to magnetic activity. Among the field late M and L dwarfs, Hα activity declines sharply as a function of effective temperature for both stars and brown dwarfs (Gizis et al. 2000). In contrast to those relatively old (>100 Myr) field dwarfs, young (<10 Myr) brown dwarfs show a wide range of behavior. Some of these youngest brown dwarfs show strong Hα emission; others show strong X-ray emission (Saffe et al. 2003; Preibisch & Zinnecker 2001; Imanishi et al. 2001; Feigelson et al. 2002, among others). Most notably, high Hα emission has been viewed as a possible sign of accretion, as in classical T Tauri stars (Muzerolle et al. 2000; Barrado y Navascues & Martín 2003; Tsuboi et al. 2003; Mohanty et al. 2003). Since the nearest star-forming regions are more than 100 pc away, detailed observations of the faintest brown dwarfs is difficult.

At a distance of only 50 pc, the TW Hya association (TWA) offers the opportunity to study a few brighter young brown dwarfs. The age is estimated to be ~10 Myr (Webb et al. 1999; Makarov & Fabricius 2001). While most of the few dozen members are pre–main-sequence stars, three brown dwarf members have been detected. TWA 5B, an M9 dwarf, was detected as a companion to a more massive primary (Lowrance et al. 1999; Neuhauser et al. 2000). The young brown dwarf 2MASSW J1207334−393254 (hereafter 2M1207) and the candidate 2MASSW J1139511−315921 (hereafter 2M1139) were identified by Gizis (2002, hereafter G02) using the Two Micron All-Sky Survey (2MASS).[1] Both 2M1207 and 2M1139 are classified as spectral type M8. TWA 5B was detected as an X-ray source by Tsuboi et al. (2003). In this Letter, we report *Chandra* observations of 2M1207.

2. DATA ANALYSIS

2.1. *Optical Data Revisited*

The original G02 spectrum showed extremely strong Hα emission of ~300 Å in two consecutive spectra. (We report emission line strengths as pseudo–equivalent widths throughout this Letter). More recent high-resolution spectra by Mohanty et al. (2003) showed emission of 28 Å—still strong, but considerably weaker. J. Kirkpatrick (2003, private communication) has kindly provided a Keck Low-Resolution Imaging Spectrograph spectrum that shows 42 Å emission. We conclude that the G02 observation captured either a flare or some other transient activity state; 2M1207 is certainly variable in its Hα strength, but all observations show strong emission. The Kirkpatrick spectrum confirms the low surface gravity and hence young age of 2M1207; Mohanty et al. (2003) conclude that the radial velocity is consistent with membership. Mohanty et al. (2003) find that the Hα is broad and conclude that 2M1207 is (weakly) accreting from a disk. Other than the emission lines, the two spectra appear very similar and, we conclude there is no sign of veiling during the high-activity state.

G02 used marginal detections on photographic plates with the 2MASS data to argue that the observed proper motion is small and consistent with TWA membership. In an attempt to confirm this result, C. Tinney (2003, private communication) obtained a *J*-band image for us using the Anglo-Australian Observatory (AAO) IRIS2 camera on 2003 June 11. We measured the position of 2M1207 with respect to other stars in the field and compared to the 1997 May 10 2MASS data. These measurements find that 2M1207 is in motion to the west (63 mas yr^{-1}) and south (40 mas yr^{-1}) as expected, but judging by the residuals in individual field stars, we estimate our measurement uncertainties to be in the range 50–100 mas yr^{-1}. Thus, these results again support a small motion and a young age, but are not adequate to definitively confirm association membership. The Deep Near-Infrared Survey detected 2M1207 with $I = 15.88 \pm 0.06$ (Epchtein et al. 2003). The *IJHK* colors are normal for an M8 dwarf and do not appear to be reddened.

2.2. *X-Ray Data*

Chandra obtained a 51 ks observation of 2M1207 in 2003 March using ACIS-S. Examination of the image reveals that no source is found at the position of 2M1207, with the maximum pixel within 5″ having a value of only 2 counts. Pixels with 2 counts are common throughout the image, and overall the characteristics of the pixels near 2M1207's position is the same as that in other comparison (sky) regions throughout the image. We conclude that we have not detected 2M1207 in X-rays, either in a quiescent or flaring state. We set a conservative upper limit of 6 photons, 3 times the maximum observed sky excursions, as our upper limit on the observed counts.

Since TWA 5B has been detected in X-rays with the same

[1] These sources appear as 2MASS J12073346−3932539 and 2MASS J11395113−3159214 in the final 2MASS release.

instrument, we use it to set the upper limits on 2M1207's X-rays. Tsuboi et al. (2003) had 35 photons detected in a 0.″7 aperture in 9.3 ks. Assuming the same distance for 2M1207, we find

$$L_{\rm X} = \frac{N}{35}\frac{9.3\ {\rm ks}}{51\ {\rm ks}} 4 \times 10^{27} {\rm ergs\ s^{-1}}.$$

Taking $N = 6$ photons, we find $L_{\rm X} < 1.2 \times 10^{26}$ ergs s^{-1}. 2M1207 is actually slightly fainter than TWA 5B ($\Delta H = 0.3$), which might be due to a lower bolometric luminosity. In this case, case we scale from TWA 5B's $\log (L_{\rm X}/L_{\rm bol}) = -3.4$ to 2M1207: $\log (L_{\rm X}/L_{\rm bol}) < -4.8$.

3. ANALYSIS

We wish to determine whether the faint X-ray luminosity is unexpected in light of the strong Hα emission. First, we compare 2M1207 to field M8/M9 dwarfs. The data for field dwarfs are sparse, but suggest that both the X-ray coronal flux and the C IV ultraviolet transition-region flux is proportional to the Hα chromospheric flux (Fleming et al. 2003; Hawley & Johns-Krull 2003), as in earlier type M dwarfs. In other words, we assume the strength of the chromosphere is proportional to the strength of the corona, and the two are physically related. We can therefore look to see whether 2M1207 has a temperature inversion resulting in a chromosphere and corona. Deep X-ray data are available for a few field M8/M9 dwarfs: LHS 2065 (Schmitt & Liefke 2002), VB10 (Fleming et al. 2003), LHS 2924 (Fleming et al. 1993), BRI 0021 (Neuhauser et al. 1999), and LP 944-20 (Rutledge et al. 2000; Martín & Bouy 2002). X-ray activity like LHS 2065 [$\log (L_{\rm X}/L_{\rm bol}) \approx -3.4$, H$\alpha$ = 8–25 Å; Martín & Ardila 2001] can be easily ruled out, and VB10-like [$\log (L_{\rm X}/L_{\rm bol}) = -4.9$] activity levels lie near our upper limits; its Hα emission is only 4.4 Å (Tinney & Reid 1998). The existing upper limit on the M9 dwarf LHS 2924 [$\log (L_{\rm X}/L_{\rm bol}) < -4.3$, H$\alpha$ = 4 Å] is consistent with the deeper VB10 detection LP 944-20's activity level [$\log (L_{\rm X}/L_{\rm bol}) < -6.2$] is well below our 2M1207 limit, but it only has 1.2 Å Hα emission (Tinney 1998). BRI 0021 is similar to LP 944-20 in that it is also rapid rotator with very weak or no Hα emission (Basri & Marcy 1995; Tinney & Reid 1998); its limit of $\log (L_{\rm X}/L_{\rm bol}) < -4.68$ is consistent with the deeper LP 944-20 data. Plainly, if young brown dwarfs behave like similar temperature, older field brown dwarfs, then the observed 2M1207 Hα emission should result in X-ray activity well above our limits. Turning the model around, the observed X-ray limits suggests that less than ~5 Å of Hα, or below 20% of the observed emission, can be due to a traditional chromosphere. The bulk of the observed Hα emission is then due to some nonchromospheric process.

Brown dwarfs in a number of young (<10 Myr) star-forming regions have been detected by *Chandra* (Preibisch & Zinnecker 2001; Imanishi et al. 2001; Feigelson et al. 2002). The detections have generally been at the $\log (L_{\rm X}/L_{\rm bol}) \approx -3$ level, while many other brown dwarfs remain undetectable in X-rays. Tsuboi et al. (2003) point out that the X-ray luminous brown dwarfs all have H$\alpha \lesssim$ 25–30 Å; those with H$\alpha \gtrsim$ 25 Å are all undetected in X-rays. This is consistent with the fact the TWA 5B was detected, but 2M1207 was not. Tsuboi et al. (2003) also point out that in the X-ray–detected objects, the Hα and the X-rays are correlated, and argue this supports a chromospheric/coronal relation. Their correlation applied to the 2M1207 upper limit suggests that less than 2.2 Å of 2M1207's Hα emission can be attributed to chromosphere. This is remarkably consistent with our results from the field dwarf comparison. By analogy with classical T Tauri stars, they attribute the high-Hα activity to star-disk interactions. Our X-ray data support the conclusion of Mohanty et al. (2003) that the broad Hα profile of 2M1207 is due to accretion. One counter argument is that 2M1207 does not show an infrared excess (Jayawardhana et al. 2003), but we note that Muzerolle et al. (2000) argued that Hα accretion remains detectable in substellar objects, while UV/optical/IR excesses do not.

We regard our results as consistent with the emerging picture that some young brown dwarfs show high activity due to star-disk interactions. Since 2M1207 is ~10 Myr old, evidently some brown dwarfs have fairly long-lived disks and ongoing accretion, or at least interactions. It is not clear whether the presence of the disk somehow suppresses the chromosphere/corona of young brown dwarfs; indeed, we do not have an observable parameter that correlates with the presence or absence of a corona. Deeper X-ray data in star-forming regions may be needed to characterize the brown dwarfs with disks.

Finally, we note that TWA 5B is probably variable in Hα, since Mohanty et al. (2003) report 5.1 Å, but Neuhauser et al. (2000) report 20 Å of emission. In this regard, it may well be similar to LHS 2065, which shows similar levels of variability (Martín & Ardila 2001) and has a similar X-ray activity level. Since both TWA 5B and 2M1207 have been observed to be quite variable, the more distant brown dwarfs in pre–main-sequence clusters also need to be monitored in Hα and X-rays (if feasible) before robust conclusions on activity can be drawn. Still, the similarity of LHS 2065 and TWA 5B is suggestive that chromospheres and coronae of objects with the same spectral types (photospheric temperatures) may be quite similar despite their different ages.

4. CONCLUSION

We report an upper limit to the X-ray activity level of the young brown dwarf 2M1207. Comparison to both field and young brown dwarfs suggests that this source must then have a weak chromosphere. We attribute the strong observed Hα emission to star-disk interactions. Activity in other objects such as TWA 5B seems to be similar to the most active field M8–M9 dwarfs, and can be attributed to chromospheres and coronae. 2M1207 is the closest known accreting brown dwarf and deserves further study at all wavelengths. We are scheduled to observe 2M1207 in the ultraviolet using the *Hubble Space Telescope* to search for a transition region, which should be weak if our interpretation of the *Chandra* data is correct.

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