Hα VARIABILITY OF THE ACCRETING YOUNG BROWN DWARF 2M 1207-3932.

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Similar to higher-mass T Tauri stars (TTS), the formation of brown dwarfs includes a phase of mass accretion from a circumstellar disk, whose presence is probed by infrared emission in excess of the photosphere (e. g. Natta et al., 2002, Jayawardhana et al. 2003a, Luhman et al. 2005, Allers et al. 2006). Spectroscopic features, such as the strength and shape of Hα emission, directly trace the accreting material. 2M 1207334-393254 (henceforth 2M 1207) is the best-studied among the brown dwarfs in the nearby (~ 50 pc) TW Hydrae association, and the oldest brown dwarf known to actively accrete from a disk, thus representing a benchmark in constraining the disk lifetimes in the substellar regime.

We have obtained a series of high-resolution optical spectra for 2M 1207 in spring 2006. Two consecutive observing nights in May 2006 at the Very Large Telescope with the UVES spectrograph yielded a timeseries with a resolution of $\sim$ 12 min. Additional optical high-resolution spectra were obtained at the Magellan Clay telescope using the MIKE spectrograph in February and April 2006.

The Hα emission of 2M 1207 is thought to be dominated by accretion: the broad wings with velocities of up to ± 200 km/s can not be explained by magnetic activity, the rotational velocity is comparatively small and can not be responsible for the broad wings, and signatures for winds are very weak (Mohanty et al., 2005; Whelan et al., 2007). The full width at 10 % of the peak height ($W_{10\,\%}$) of Hα has been established as a reliable accretion indicator: Objects with $W_{10\,\%} > 200\,\mathring{A}$ can be considered accretors (Jayawardhana et al., 2003b).

Fig. 1 shows the time-series of some relevant line parameters obtained during our run with UVES. The 10 % width is clearly above the accretion threshold throughout our observation ($W_{10\,\%} \approx$ 280...320 km/s); on average it is higher during the second night, in the course of which it slightly declines. The equivalent width (W_{EQ}) has ups and downs during the first night, and has its maximum at the beginning of the second night, after which it declines dramatically and in a continuous way until the end of the observation.

The Hα emission is double-peaked throughout all observations from February to May 2006. Fig. 2 displays a sequence of four normalized line profiles, each representing the average of four frames obtained with UVES on May 8, 2006. For clarity, the spectra are plotted with different vertical offsets.

Scholz et al. (2005) have shown that the double-peaked Hα profile of 2M 1207 can be interpreted as a broad emission line onto which a red-shifted absorption component is superposed. For the minimum of the absorption feature we measure a position that varies in the range $\Delta v_{min} \approx -10... + 70$ km/s with respect to the expected wavelength. From Fig. 1 it appears that twice during the extensive monitoring in May 2006 v_{min} undergoes a discrete jump from high redshift towards the expected line center. These times correspond to line profiles in which the absorption trough is wide and asymmetric, such that the position of the minimum can not be determined precisely (second profile from the top in Fig. 2). As a measure for the asymmetry of the emission component, Fig. 1 shows the difference between the 10 % width on the blue (left) and on the red (right) side of $\Delta v = 0$. In the course of the UVES observations, $W_{10\,\%}(l - r)$ varied from $-40... + 40$ km/s. In particular, during the second night the line moved systematically from the blue to the red. This is in contrast to the absorption feature shown above to be redwards of $\Delta v = 0$ throughout the observation (cf. also Fig. 2).

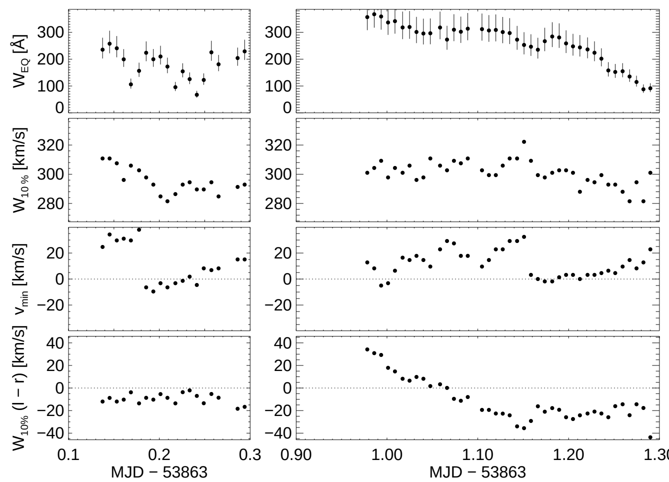

Figure 1: Temporal evolution of parameters characterizing the Hα emission of 2M 1207 during May 8-9, 2006.

Within the two nights of near-continuous observation in May 2006 there is clear variability present in the Hα emission, but it is much less pronounced and systematic than expected from previous data. Therefore, either the accretion stream is nearly homogeneous over (sub)stellar longitude or the system is seen face-on. The former interpretation seems more likely, as high inclination has been inferred from the shape of the Hα profile and the timescale of its variability during 2005 where the absorption reversal appeared and disappeared within one rotation cycle (Scholz et al. 2005).

The small but significant variations of the Hα profile evident throughout our near-continuous observation in May 2006, reach a maximum after ~ 8 h, roughly the timescale on which

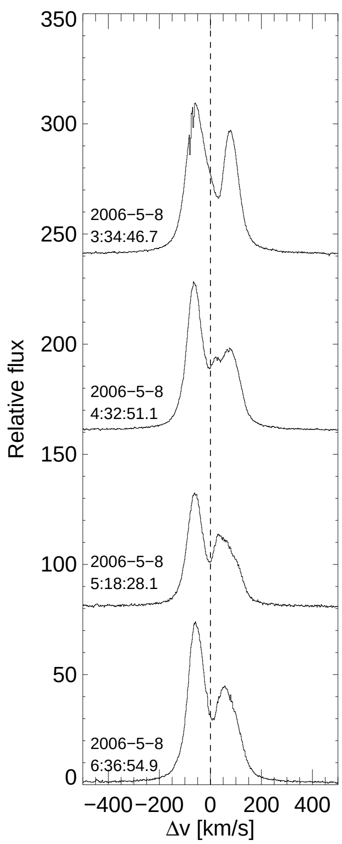

Figure 2: Sequence of normalized average Hα line profiles of 2M 1207 obtained with UVES in May 2006.

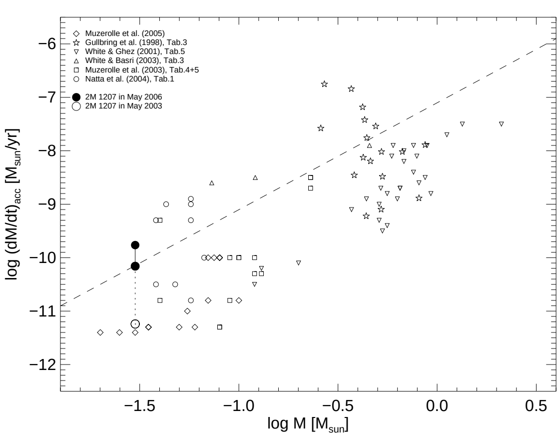

Figure 3: Relation between mass and mass accretion rate for sub-stellar objects; data from the literature cited by Muzerolle et al., (2005).

maximum variability is expected across the rotation cycle. This makes rotation a plausible origin for the short-term variability.

From Eq. 1 of Natta et al., (2004), we find an accretion rate of $10^{-10.1...-9.8}\ M_{\odot}/yr$ for the range of Hα 10 % widths measured for 2M 1207 in May 2006. In previous measurements, $\dot{M}_{acc}$ was as low as $\sim 10^{-11.2}\ M_{\odot}/yr$, i.e. 2M 1207 changes its accretion rate by a factor of 2 on the timescale of days, and at least by one order of magnitude over the years. In Fig. 3 we put 2M 1207 in the context with other accreting (sub)stellar objects. A correlation between accretion rate and mass ($\dot{M}_{acc} \sim M^{\alpha}$ with $\alpha \approx 2$) has been reported in the literature. The range of $\dot{M}_{acc}$ inferred from all available data of 2M 1207 is indicated by large circles connected by a vertical line. We point out that the range of mass accretion rates derived for 2M 1207 is comparable to the spread in the $\dot{M}_{acc} - M$ relation. Therefore, variability might indeed explain this spread. Repeated measurements of $\dot{M}_{acc}$ for known accretors will be helpful to verify our suggestion.

According to Koenigl (1991) the mass accretion rate of TTS is related to their magnetic field strength,

$$B \sim \dot{M}^{1/2} \cdot M_{*}^{1/4} \cdot R_{*}^{-3} \cdot R_{t}^{7/4}. \quad (1)$$

We assume $R_t \sim 2R_*$ for the disk truncation radius (Muzerolle et al. 2000). The mass and radius of 2M 1207 are $M_* = 0.03\,M_{\odot}$ and $R_* = 0.27 R_{\odot}$ (Chabrier et al. 2000). Taking account of the scaling factors, the average accretion rate of 2M 1207 observed in May 2006 ($\dot{M} \sim 10^{-10}\ M_{\odot}/yr$) yields an approximate value for the surface field, $B \approx 200$ G. The same equation yields for a TTS with $0.8\,M_{\odot}$, $1.5\,R_{\odot}$, and $\dot{M} \sim 10^{-8}\ M_{\odot}/yr$ a surface field of $\approx$ 600 G. This value is somewhat lower than measured values for TTS, which are typically in the kilogauss range (e.g. Yang et al. 2005 and references herein). There are, however, considerable uncertainties connected with the use of the Koenigl-relation, such as the simplified assumption of a dipolar field and the location of the inner disk radius with respect to the corotation radius that determines the scaling factor. Given these ambiguities, the order of magnitude agreement between the estimated and observed fields is plausible.

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