Mem. S.A.It. Vol. 84, 1107

Memorie della

X-Shooter spectroscopy of brown dwarfs in the TW Hya association

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Abstract. We present broad-band mid-resolution X-Shooter/VLT spectra for four brown dwarfs of the TW Hya association. Our targets comprise substellar analogs representing the different evolutionary phases in young stellar evolution. In the two diskless brown dwarfs we determine the stellar parameters and we study their chromospheric emission line spectrum. For the two accreting brown dwarfs we estimate the mass accretion rates.

Key words. Stars: pre-main sequence, fundamental parameters, activity, chromospheres, accretion

1. Introduction

We discuss optical and near-infrared spectra of four brown dwarf members of the TW Hya (TWA) association. The data have been obtained with the broad-band (350 – 2500 nm) spectrograph X-Shooter at the VLT as part of the INAF consortium's Guaranteed Time observations (see Alcalá et al. 2011). The target list with spectral types and distances adopted from the literature and the observing log are presented in Table 1. X-Shooter spectroscopy enables a detailed characterization of young (sub)stellar objects, including an accurate assessment of their fundamental parameters, kinematics, rotation, and magnetic activity. It provides a rich database of accretion diagnostics from the Brγ and Paβ lines in the near-IR to the Balmer jump in the UV including the full optical band with the Balmer series and He I lines and the Ca IRT. Finally, outflows can be traced through forbidden line emission.

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2. Results

Based on the presence or absence of a measurable Balmer jump we have classified the observed TWA brown dwarfs as accretors or non-accretors, approximated here by the young stellar object (YSO) classes II and III (see Table 1). The result is consistent with the previous literature where TWA 26 was identified as a Class III source through the absence of near-IR excess in its spectral energy distribution (Morrow et al. 2008), while TWA 27 and TWA 28 display IR excess (Riaz et al. 2006; Harvey et al. 2012). TWA 27 is also known to be accreting (Scholz et al. 2005) and to drive an outflow (Whelan et al. 2007). The coolest target, TWA 29, had not yet been investigated for its disk, accretion and outflow properties.

Table 1. Observing log for X-Shooter spectroscopy of TWA brown dwarfs

TWA number	other designation	SpT	d [pc]	YSO Class	Obs.date [dd/mm/20yy]	Slit width UVB/VIS/NIR
26	2M J1139-3159	M8...M9	42	III	22/03/10	1.0"/0.9"/0.9"
27	2M J1207-3932	M8	53	II	22/03/10; 19/04/12	1.0"/0.9"/0.9"
28	SSSPM J1102-3431	M8.5	55	II	22/03/10	1.6"/1.5"/1.5"
29	DENIS-P 1245-4429	M9.5	79	III	22/03/10	1.6"/1.5"/1.5"

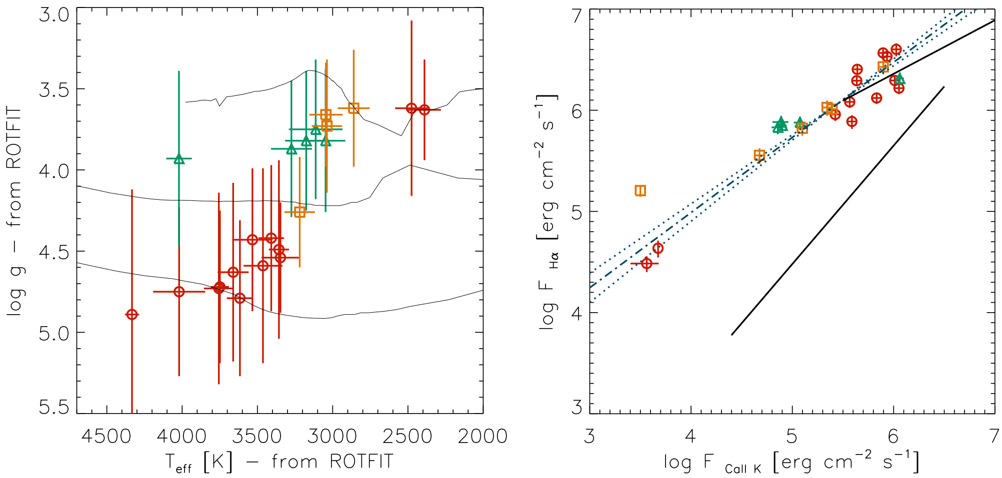

Fig. 1. (left): Surface gravity and effective temperature measured from the X-Shooter spectrum for Class III sources compared to the 1, 10, and 100 Myr isochrone from Baraffe et al. (1998) and Chabrier et al. (2000) models. (right): Flux-flux relation for chromospheric Hα and Ca K emission for Class III sources from our X-Shooter program. Dash-dotted and dotted are the linear regression and its uncertainty. The two solid lines denote the 'active' (upper) and 'inactive' (lower) branches identified by MA11 for field dwarf stars. Different plotting symbols for different regions: circles - TWA, squares - Lupus, triangles - σ Orionis. TWA 26 and TWA 29 are the coolest objects with the smallest line fluxes within the TWA sample.

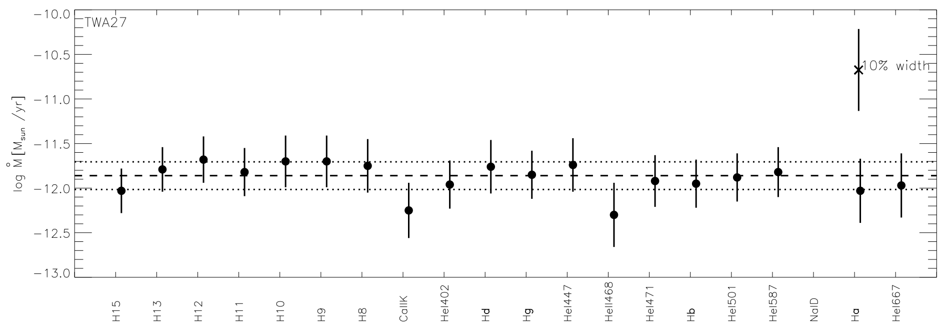

Fig. 2. Mass accretion rate of TWA 27 from empirical relations between accretion luminosity and luminosity of emission lines. Dashed and dotted lines are mean ($\langle \log \dot{M}_{\rm acc,line} \rangle = -11.9$) and its 1 σ uncertainty.

2.1. Non-accreting brown dwarfs

For TWA 26 and TWA 29 and all the other Class III sources observed within our X-Shooter program we have performed a systematic assessment of their fundamental parameters, radial velocity and rotational velocity using the ROTFIT routine (see Frasca et al. 2006). In Fig. 1 (left) we show the results for surface gravity and effective temperature compared to evolutionary models from Baraffe et al. (1998) and Chabrier et al. (2000). Generally, we find lower gravities for the Class III stars in Lupus and σ Orionis with respect to TWA. This is qualitatively consistent with the known age difference between these star forming regions but the values of the $\log g$ in TWA are higher than predicted for $10 - 15$ Myr old objects by the evolutionary models. The two brown dwarfs have lower gravity than the early- to mid-M stars in the TWA, similar to the results of Mohanty et al. (2004) for a sample of brown dwarfs in the 5 Myr-old UpperSco region. The temperature region around $T_{\rm eff} \approx 2500$ K is characterized by the onset of dust formation and we conjecture that this aspect is not yet properly treated in the stellar models.

We have measured emission lines fluxes to assess the characteristics of the chromospheres for the Class III sample, including TWA 26 and TWA 29. The correlation between the surface fluxes of Hα and Ca K emission is shown in Fig. 1 (right). It is different from the relation presented by (Martinez-Arnaiz et al. 2011, MA11) for the bulk of field FGKM dwarfs (lower solid line in Fig. 1 right). Our data are, instead, roughly consistent with the 'active' branch identified by MA11 for a subsample of field M dwarfs (upper solid line) and we extend this upper branch to two dex lower fluxes.

2.2. Accreting brown dwarfs

For the two accretors, TWA 27 and TWA 28, we have measured the mass accretion rate from empirical relations between the accretion luminosity and the emission line luminosity of the form $L_{\rm acc} = a + b \cdot L_{\rm line}$. Here, $L_{\rm acc}$ represents the UV excess emission with respect to a template spectrum of a non-accreting star of the same spectral type. It is obtained by adding the continuum emission of a hot slab of hydrogen gas to the template spectrum and fitting it to match the observed spectrum of the accretor. The coefficients a and b have been determined for 39 emission lines from a large sample of accreting YSOs in Lupus observed during our program (Alcalá et al., in prep.). The mass accretion rate, $\dot{M}_{\rm acc}$, is given as $\dot{M}_{\rm acc} = 1.25 \cdot L_{\rm acc} R_* / GM_*$ (see e.g. Gullbring et al. 1998). The values obtained for TWA 27 are shown in Fig. 2. The $\dot{M}_{\rm acc}$ we derive from the Hα 10 % width using the relation of Natta et al. (2006) is in disagreement with the values from the line luminosities, possibly due to outflow contributions in the Hα wings. In an analogous way we find for TWA 28 from the line luminosities $\langle \log \dot{M}_{\rm acc,line} \rangle = -12.2 \pm 0.2$ and from the Hα 10 % width $\log \dot{M}_{\rm acc,H\alpha 10\%} = -11.3 \pm 0.4$. We conclude that the 10 % width of Hα emission, although efficient for identifying accretors, is not suited for quantitative measures of mass accretion. With these X-Shooter observations we are pushing into very low values for $\dot{M}_{\rm acc}$, close to the limit where lines are dominated by chromospheric emission (Manara et al. 2013).

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