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A VLT/X-Shooter study of accretion and photoevaporation in Transitional Disks

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Abstract. We present preliminary results of a detailed study of the accretion, stellar, and wind properties of transitional disks (TDs) carried out with the X-Shooter spectrograph. Combining new and archival spectra, we collected a sample of more than 20 TDs from different nearby star-forming regions. Our sample includes objects with both small (<5-15 AU) and large (>20–30 AU) known inner hole size from the literature (either from mm-observations or IR SED fitting). We check their stellar parameters ($T_{\rm eff}$, L_*, A_V, M_*) and derive their accretion properties ($L_{\rm acc}$, $\dot{M}_{\rm acc}$) in a self-consistent way, which makes use of the wide wavelength coverage of X-Shooter, and study their wind properties by mean of different forbidden emission lines analysis.

Keywords. stars: formation, stars: pre–main-sequence, planetary systems: protoplanetary disks

1. Introduction

Transitional Disks (TDs) are considered to be a late evolutionary stage of optically thick massive disks whose inner regions are being evacuated, leaving behind large holes that can be detected both by modeling the infrared spectral energy distribution (SED) or, in some cases, by mm-interferometry. These holes could be produced by processes of photoevaporation, grain growth, or planet formation. Still, none of these processes alone has been shown to be sufficient to explain all observations. In this context, the combination of inner hole size, mass accretion rate ($\dot{M}_{\rm acc}$) and wind properties is a powerful observational diagnostic of disk evolution models, but the current measurements of $\dot{M}_{\rm acc}$ for TDs are mostly based on secondary indicators (such as the 10% Hα width), and very few data on the wind properties for these objects are available.

2. Method

Accretion and spectral type fitter: We fit the observed spectra of our targets with a grid of models that include a range of photospheric template spectra (Class III YSOs from Manara *et al.* 2013a, augmented with some earlier spectral type (SpT) templates), a range of possible values for the extinction and for the excess spectrum produced by the disk accretion process, modeled as an isothermal hydrogen slab emission (for a detailed description of the method see Manara *et al.* 2013b). With the best fitting model (see Fig. 1a) we derive self-consistently from the complete X-Shooter spectrum SpT, A_V, and $L_{\rm acc}$ for the input target. In general, but with some notable exceptions (see Sect. 3), our findings confirm or slightly modify previous values available in the literature.

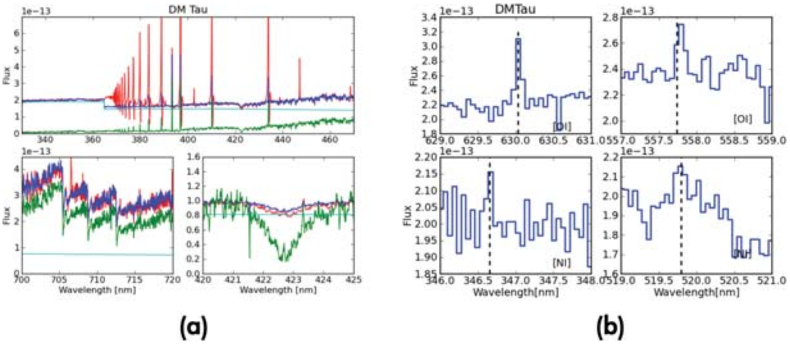

Figure 1. *(a)*: Example of fitting procedure described in Sect. 2. We show the Balmer jump fit, the normalization region, and the veiled Ca I line. *(b)*: Example of forbidden emission lines.

Forbidden lines: We search for emission in various forbidden lines to check for the presence of winds and disk photoevaporation in each source. In particular, we check various [OI] lines ($\lambda\lambda = 630, 636.4, 557.7$ nm), the [NI] lines ($\lambda\lambda = 519.8, 346.6$ nm), and the [SII] line at $\lambda = 673.1$ nm (see Fig. 1b). A clear detection of all these lines is usually evidence of outflows, possibly caused by disk photoevaporation. In order to asses that, we have to study in detail the kinematics and intensity of these lines.

3. Results and discussion

We confirm that the TD SR21 ($\mathrm{R_{in}} = 36$ AU) is not accreting. The X-Shooter spectrum of this object does not show any signature of accretion, neither in the UV excess or in the emission lines. Another notable exception is Ser29, (SSTc2d J182911.5 + 002039, $\mathrm{R_{in}} = 8$ AU), for which we find a value of $\dot{M}_{\rm acc} = 1.6{\cdot}10^{-9} M_{\odot}$/yr instead of the one reported in the literature, which is $\dot{M}_{\rm acc} \sim 10^{-7} M_{\odot}$/yr (Merìn *et al.* 2010). Most of the objects with large inner holes ($\mathrm{R_{in}}$ >30 AU, e.g. SR21, LkHα330, RX J1615) do not show the signatures expected from photoevaporating winds (forbidden line emission). On the contrary, most of the objects with $\mathrm{R_{in}} < 25$ AU show forbidden line emission.

Disk accretion signatures have been used to exclude the possibility that photoevaporation plays a dominant role in the disk clearing process (e.g. Espaillat *et al.* 2010), because gas should not be anymore present in the inner-hole if photoevaporation is occuring. As opposite to that, planet induced gaps may still allow for large values of $\dot{M}_{\rm acc}$. On the other hand, photoevaporation models predict ongoing accretion for $\sim 10^{-5}$ years after hole opening, while the hole is still small (Owen *et al.* 2012). In our sample we see that some objects with very large inner holes, i.e. $\mathrm{R_{in}} > 30$ AU, in particular SR21, have low or negligible accretion, and their inner holes could be possibly originated by photoevaporation. At the same time, there are some TDs with large inner holes and not negligible accretion rates ($\dot{M}_{\rm acc} \gtrsim 10^{-9} M_{\odot}$/yr) for their masses ($M_* \gtrsim 1 M_{\odot}$) that, within the current theoretical framework, could be explained only with planet formation models. More analysis on their wind and stellar properties will help to understand their real origin.

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