UNDERSTANDING THE ORIGIN OF THE [OI] LOW-VELOCITY COMPONENT FROM YOUNG STARS

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Abstract

Accretion of matter onto the central star, protostellar winds/jest, disk winds, photoevaporative winds operate concurrently in dispersing protoplanetary disks. Disentangling their relative contribution requires identifying diagnostics that trace different star-disk environment. Here we analyze the low-velocity component (LVC) of the [O I] 6300Å, 5577Å lines. We compare these lines to the LVC of the [Ne II] 12.81µm (which has been found to trace photoevaporative disk winds driven by stellar X-ray/EUV photons [1,2,3]) and to the narrow component (NC) of the CO fundamental band at 4.7µm (which has been proposed as disk wind tracer [4,5]). We find that these three diagnostics may arise from different regions around the star. We find that the luminosity of the [O I] LVC is proportional to the stellar FUV luminosity, and we show that the [OI] 6300Å/5577Å line ratio is low. These findings favor an origin of the [OI] LVC in a region where OH is photodissociated by stellar FUV photons. A detailed modeling of the highest resolution spectra reveals multiple components within the [OI] LVC, with one component likely tracing a photoevaporative wind either driven by stellar FUV and/or X-ray photons.

The sample: To compare different disk dispersal tracers we have collected a sample of 8 objects with high-resolution spectra and detection of at least two tracers between [OI] LVC, [NeII] and CO. To test the correlation between the [OI] LVC and stellar properties we have re-analyzed the survey of T Tauri stars in Taurus published in Hartigan et al. (1995).

Line profile comparison: The comparison between disk dispersal tracers show that they are likely tracing different regions around the star: i) the [OI] LVC is broader and less blueshifted than the [NeII]; ii) the [OI] LVC is more blueshifted than the CO; iii) FWHMs do not follow a simple trend. These trends are consistent with a scenario in which [NeII] traces mostly the upper surface of a photoevaporative wind at larger radii than CO and [OI] LVC.

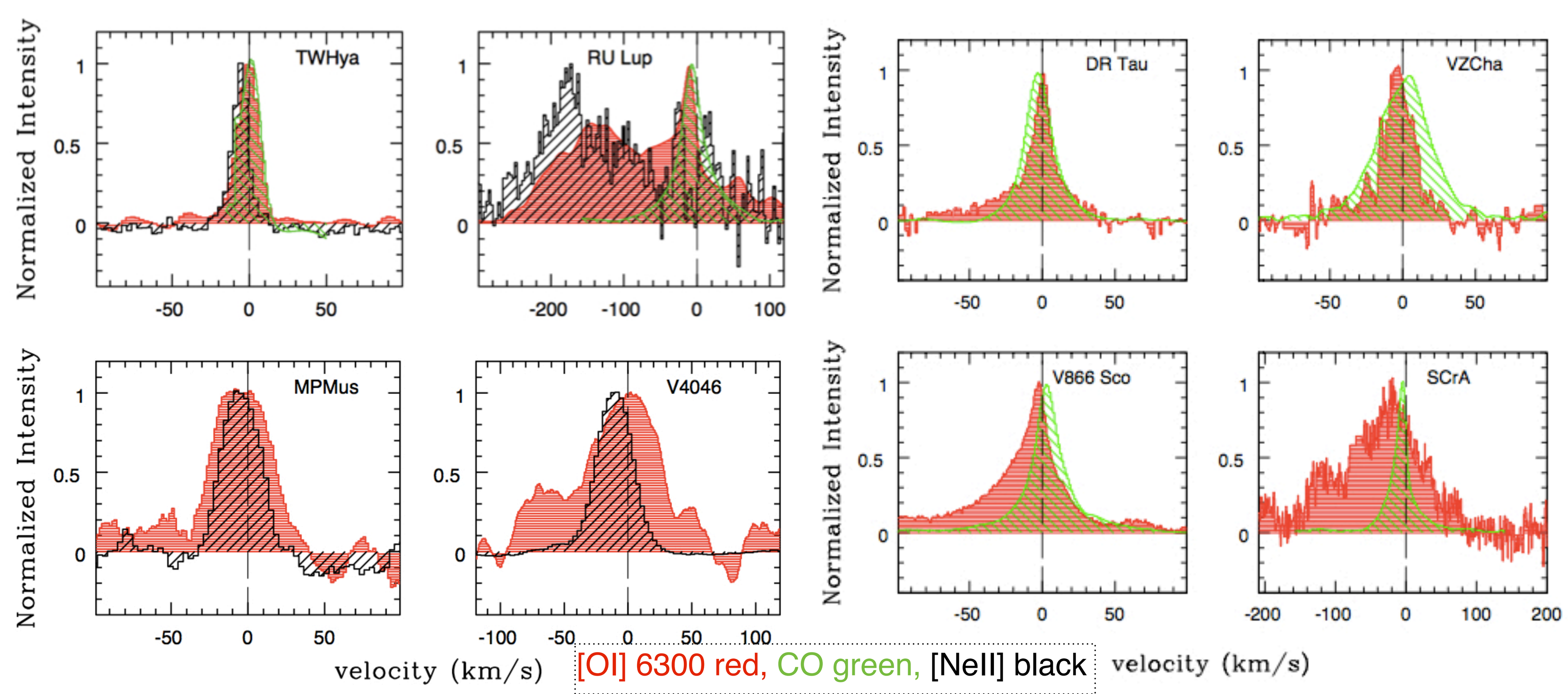
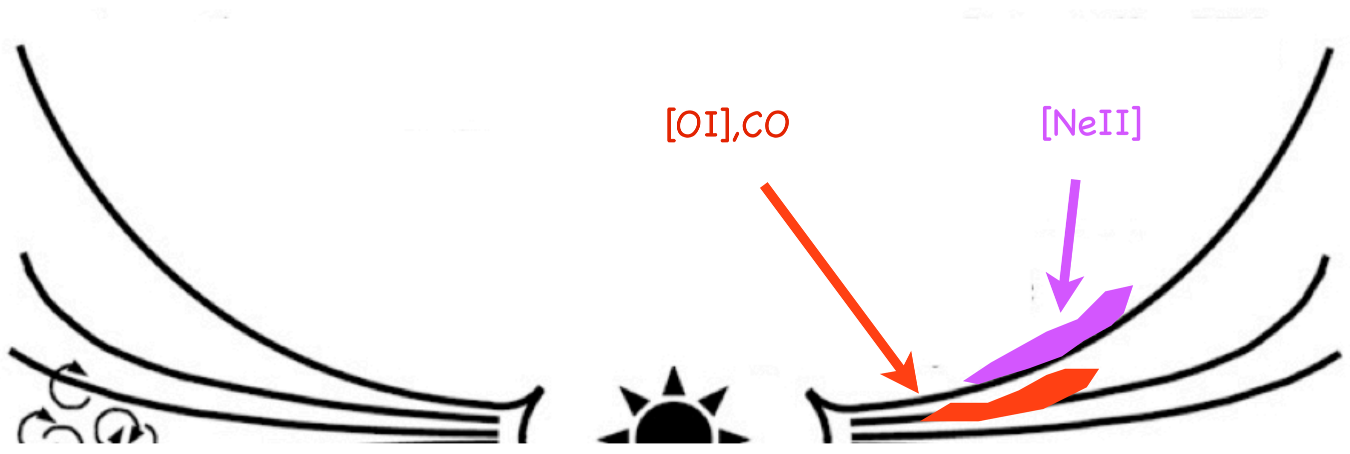
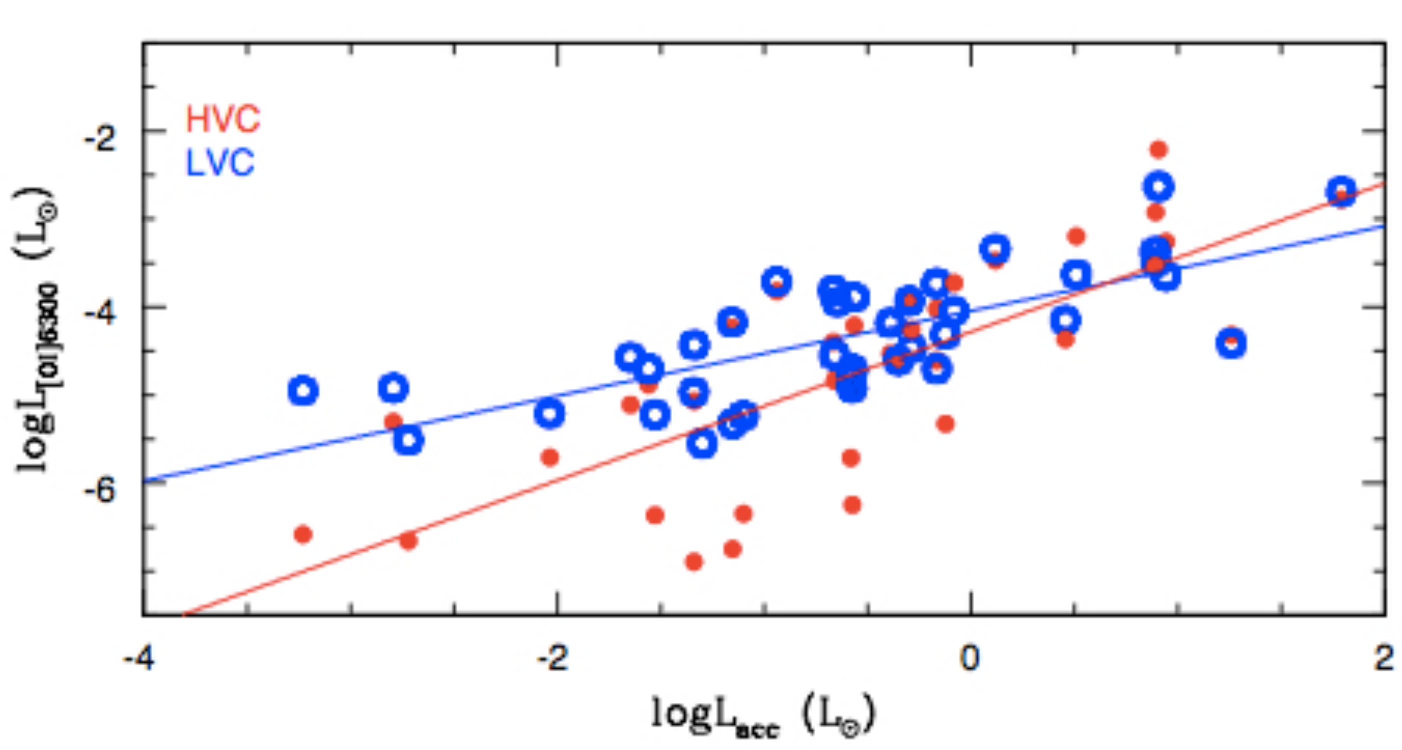
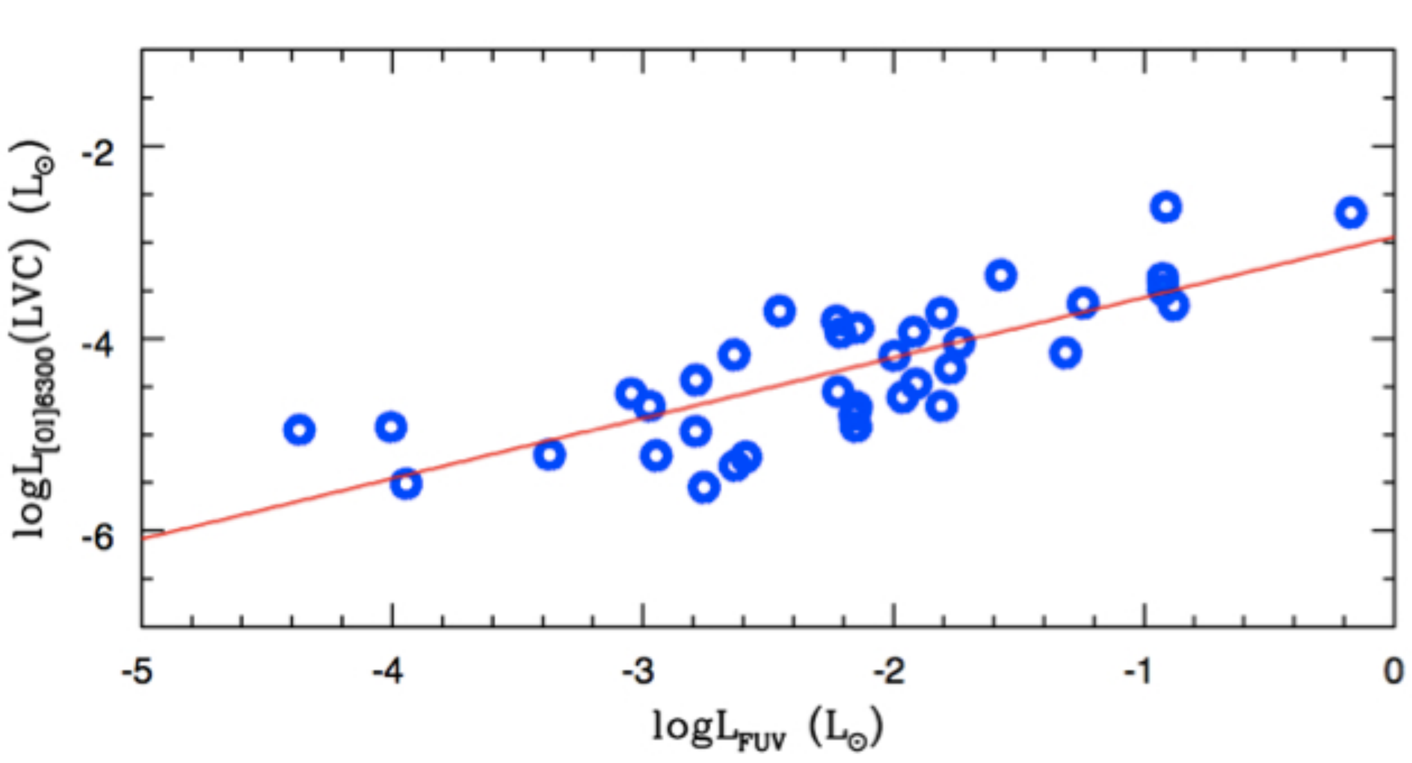


Fig.1: Normalized profiles of the 3 disk dispersal diagnostics. If all tracers are from photoevaporative flows, they must trace different physical regions of the flow (Rigliaco et al. 2013). Profiles from [2,4,9, Rigliao et al. 2013]







Correlation with stellar properties: We fins a correlation between the [OI] LVC luminosity and the accretion luminosity (L_{acc}) we have computed from the equivalent width of the Hα line [6]: $\log L_{[OI]LVC} = (0.52\pm0.07)\times\log L_{acc} - (3.99\pm0.09)$. Using the correlation between L_{acc} and the total FUV luminosity found by Yang et al. (2012) we convert the previous relationship into: $\log L_{[OI]LVC} = (0.63\pm0.09)\times\log L_{FUV} - (2.94\pm0.21)$. ***Higher accreting stars have higher FUV luminosity and higher [OI] LVC luminosity.*** We find that the typical [OI]LVC 6300Å/5577Å line ratio range between 1 and 8 (with a mean value of ~5) and remain almost constant over a large range of L_{acc}. These low ratios, if thermal in origin, need emission coming from a very hot (T~5000-8000K) and dense (n_e~10^7-10^9 cm^{-3}) gas [7,8]. These physical conditions are unlikely in disks, especially in the photoevaporative flows. However, ***these low ratios can be obtained from FUV photodissociation of OH***. Moreover, the observed FWHMs are larger than those predicted by models accounting for gas photoevaporating from the disk surface. ***These larger FWHMs suggest an origin of the line in the inner part of a disk in Keplerian rotation.***

Two components in the [OI] LVC: The analysis of the two highest resolution and S/N spectra shows that the [OI] LVC traces at least two different components: a narrow component (NC-LVC) with a central peaked emission, and a broad component (BC-LVC) accounting for the broader wings emission. The BC-LVC has FWHM~40-60km/s and points to [OI] gas as close as 0.6AU. The NC-LVC has FWHM~10km/s and might be associated with the portion of the [OI] gas that becomes gravitationally unbound at radial distances >10AU.

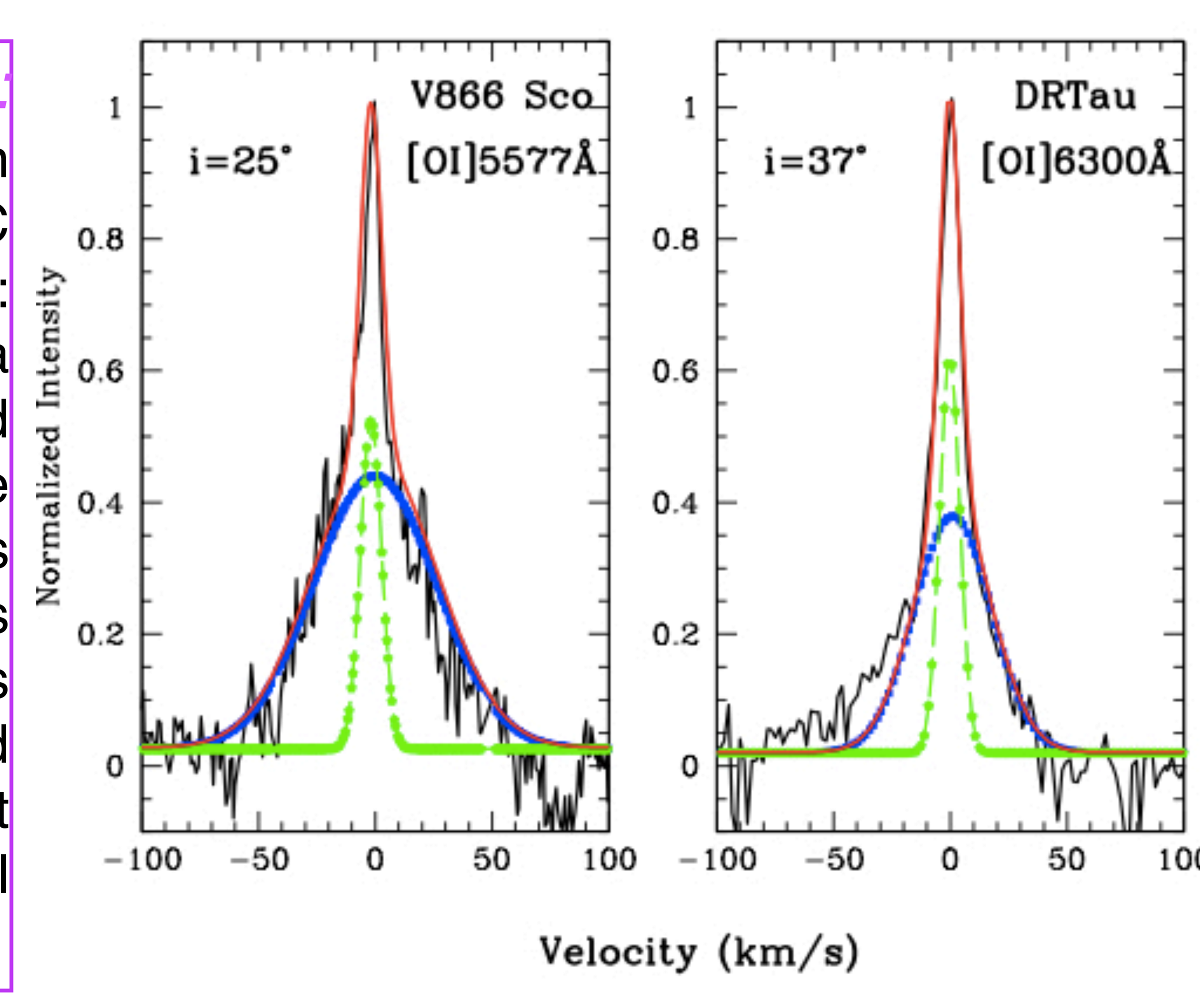


Fig.5: Double gaussian fit for DRTau and V866 Sco line profiles. Black: observed profile; red: summed profile; green: NC-LVC; blue: BC-LVC

Proposed Scenario

Stellar FUV photons penetrate the outflow column of classical T Tauri stars and reach the disk surface where they dissociate the OH molecules. Higher accretion rates imply higher FUV luminosities, higher rate of OH dissociation, and hence higher [OI] luminosities as observed. This photodissociated layer may have a bound component of gas in Keplerian rotation, and unbound gas at radial distances >10AU, ***likely a photoevaporative wind***. This wind is heated by either the same FUV photons that dissociate OH molecules, or by hard (>1KeV) photons that can also penetrate the outflow column. These hard X-ray photons may be responsible for producing the [NeII] blueshifted emission from gas at higher vertical heights of the photoevaporative flow.

References:
[1] Pascucci, I. & Sterzik, M. 2009, ApJ, 702, 724; **[2]** Sacco et al. (2012), ApJ, 747, 142; **[3]** Baldovin-Saavedra et al. 2012, A&A, 543, 30; **[4]** Bast et al. (2011), A&A, 527, 119; **[5]** Brown et al. 2013, arXiv:1304.4961; **[6]** Rigliaco et al. 2012, A&A, 548, 56; **[7]** Kwan & Tademaru 1995, ApJ, 454, 382, **[8]** Gorti et al. (2011), ApJ, 735, 90; **[9]** Pascucci et al. (2011), ApJ, 736, 13; Hartigan et al. (1995), ApJ, 452, 736; Yang et al. (2012), ApJ, 744, 121; ***Rigliaco, E., Pascucci, I., Gorti, U., Edwards, S., Hollenbach, D. 2013, Accepted by ApJ***.