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# Spectroscopic diagnostics of T Tauri inner winds

**Suzan Edwards**

Department of Astronomy, Smith College, Northampton, MA 01063, USA
email: sedwards@smith.edu

**Abstract.** The role of the star-disk interaction region in launching the high velocity component of accretion-driven outflows is examined. Spectroscopic indicators of high velocity inner winds have been recognized in T Tauri stars for decades, but identifying the wind launch site and the accompanying mass loss rates has remained elusive. A promising new diagnostic is He I $\lambda$10830, whose metastable lower level results in a powerful probe of the geometry of the outflowing gas in the interaction region. This, together with other atomic and molecular spectral diagnostics covering a wide range of excitation and ionization states, suggests that more than one launch site of the innermost wind is operational in most accreting stars.

**Keywords.** Stars:pre–main-sequence, mass loss, winds, outflows.

## 1. Historical perspective

The presence of high velocity winds from T Tauri stars, heralded by blueshifted absorption features cutting into strong and broad permitted emission lines, has been recognized for nearly half a century. A series of increasingly sophisticated attempts to determine mass loss rates from T Tauri stars over a period of several decades assumed that both the emission and absorption components of H$\alpha$ were formed in spherically symmetric stellar winds (Kuhi 1964; Hartmann, Edwards & Avrett 1982; Natta, Giovanardi & Palla 1988; Hartmann *et al.* 1990). However, several issues were perplexing. One was the difficulty in powering energetic winds, since thermal coronal stellar winds were shown by de Campli (1981) to have a firm upper limit of $10^{-9}$ $M_\odot$ yr$^{-1}$, while mass loss rates from strong emission T Tauri stars could exceed $\dot{M}_w \sim 10^{-7}$ $M_\odot$ yr$^{-1}$. Another was that the line profiles predicted for stellar winds had a classic P Cygni character, unlike the majority of T Tauri H$\alpha$ profiles where the blue absorption was typically at velocities considerably less than the broad emission wings and rarely penetrated the continuum.

The concept of a T Tauri stellar wind crumbled when it became clear that disk accretion was the energy source for T Tauri activity. Magnetospheric accretion, where funnel flows channel matter from the disk truncation radius to the star, became the favored source of line *emission* (Basri & Bertout 1989; Hartmann, Hewett & Calvet 1994). Blueshifted forbidden lines were recognized as superior diagnostics of mass outflows, leading to a decline of interest in the blueshifted absorption features in strong permitted lines. Forbidden lines became the basis for establishing what is now known as the accretion/outflow connection (Cabrit *et al.* 1990; Hartigan, Edwards & Ghandour 1995), and centrifugally powered disk winds were soon considered the likely source of T Tauri outflows. In recent years, however, the possibility that accretion-powered stellar winds may be significant contributors to mass ejection in accreting systems is now being re-examined. In this chapter we review the observational diagnostics of the inner regions of accretion-powered winds with the aim of clarifying where and how they originate.

## 2. Outflows from accreting protostars and T Tauri stars

A symbiotic relation between accretion and outflow persists from the youngest, most deeply embedded protostars through to the final stages of disk accretion when the central star is optically revealed as a classical T Tauri star. At spatial scales from tens of AU to several parsecs from the star, collimated jets of shocked gas and expanding lobes of swept up molecular gas provide the means of diagnosing outflow energies, momenta, and mass loss rates (Bally *et al.* 2007). The resultant correlations between diagnostics of the wind mass loss rate $\dot{M}_w$ and the disk accretion rate $\dot{M}_{acc}$ clarify that the outflows are accretion powered (see chapter by S. Cabrit), although how they are launched remains a mystery. Accretion powered outflows are suspected to play a major role in the angular momentum evolution of an accretion disk system, likely extracting angular momentum from the accreting star and/or the accretion disk (chapters by J. Bouvier, F. Shu, J. Ferreira). They also have the potential to disrupt infalling cores, thus limiting the mass of the forming star, and to affect cloud turbulence, especially on local scales (Nakamura & Li 2007).

The basic energy source for the outflows is thought to be magnetohydrodynamic in origin, with launch occurring in a region where open magnetic field lines anchor to a rotating object and collimation is provided by hoop stresses from the toroidal field, focusing the flow toward the rotation axis (Ferreira *et al.* 2006). Three basic steady state MHD ejection scenarios are under consideration, each with different implications for how angular momentum will be extracted from the star and disk. A widely explored option assumes that the inner disk has a sufficient magnetic field and ionization fraction to launch centrifugal winds over a range of disk radii from the inner truncation radius out to several AU (Pudritz *et al.* 2007). Another strong contender is a modified disk wind restricted to a narrow region near corotation where centrifugal launching is enhanced by a hijacked stellar field, providing strong magnetic channeling from an “X” point (Shu *et al.* 2000).

A third option is that some form of accretion-powered stellar wind is operating, where winds emerge along field lines anchored to the star (Kwan & Tademaru 1988; Hirose *et al.* 1997; Romanova *et al.* 2005). There are reasons to be skeptical of this option as an important source of mass loss, since X-ray fluxes are several orders of magnitude too small to provide launching via coronal thermal pressure (see chapter by S. Matt) and by the T Tauri phase the stars are spinning too slowly for effective centrifugal launching (see chapter by J. Bouvier). However, both theoretical and observational considerations have recently surfaced that suggest stellar winds need to remain as a contender. On the theoretical side, doubts have been raised as to whether disk winds can brake accreting stars to their observed slow spin rates (von Rekowski & Brandenburg 2006; Matt *et al.* 2005) and on the observational side the resonance profiles of a new spectroscopic diagnostic, He I $\lambda$10830, appear to require acceleration in a flow moving radially away from T Tauri stars with high disk accretion rates (Edwards *et al.* 2003; Kwan, Edwards & Fischer 2007). If so, then a robust means of accelerating an MHD stellar wind would need to be identified, possibly relying on Alfven waves or magnetic reconnection.

Ultimately the verdict on how accretion powered winds are launched will be established empirically. Observations of the collimation and kinematic structure of spatially resolved jets within 10-100 AU of the star hold valuable clues to wind origins (see chapters by T. Ray and S. Cabrit for a full discussion of this topic). For example, the poloidal velocity field inferred from channel maps reconstructed from multiple long-slit HST spectra of the jet from the high accretion rate TTS DG Tau suggests that the highest velocity gas (several hundred km s$^{-1}$) is confined to the jet axis, sheathed by concentric rings of slower moving gas (Bacciotti *et al.* 2002). Such kinematic structure is suggestive of extended MHD disk winds, where ejection velocities will scale with disk radii in proportion to the the associated Keplerian velocity, yielding higher velocity flows from the inner disk and slower flows from more distant regions. However, a growing number of spatial-velocity maps from long slit spectra acquired with adaptive optics on large ground based telescopes suggest that two separate ejection processes may be operational (Pyo *et al.* 2003). High and low velocity components (HVC and LVC, respectively) with distinctive spatial characteristics are often seen on the smallest spatial scales, but there is no consensus on what their separate origins might be. Possibilities include attributing the HVC to a disk wind and the LVC to entrained gas or attributing the HVC to a wind from the disk X-point (or a stellar wind), and the LVC to an extended disk wind (Takami *et al.* 2006; Pyo *et al.* 2006).

Clearly, definitive observational evidence for wind origins requires probes that reach closer to the launch sites. Interferometers working in the near IR are beginning to give some information on disk structure in the inner AU (see chapter by F. Malbet), but for now high resolution spectroscopy is the prime means of probing the inner disk and the star/disk interaction region where the winds are actually launched. From high resolution line profiles of molecular and atomic features we hope to elucidate the origin of the high and low velocity flows seen in the jets, using profile kinematics and physical conditions for line formation to provide clues to how/where accretion powered winds arise.

## 3. Winds from the inner disk?

A number of ro-vibrational molecular emission lines are attributed to formation in the inner disk, including C0, $H_20$, OH, $H_2$, HCN, $C_2H_2$ (Najita *et al.* 2007). The highest detection frequency in surveys of accreting stars is for the 4.6$\mu$ CO fundamental, which displays broad, centrally peaked, symmetric emission profiles centered on the stellar velocity. The lines are well modeled as simple Keplerian rotation over a range of radii in the inner disk, from the inner truncation radius ($\leqslant 0.1$ AU) out to 1-2 AU (Najita *et al.* 2003). This range of radii is precisely the regime where centrifugally launched disk winds are expected to originate. Thus, if disk winds are launched between 0.1 to 2 AU, the acceleration region must lie higher above the disk plane than the temperature inversion layer where the CO fundamental arises, characterized by excitation temperatures $\sim 1000K$ and CO column densities $\sim 10^{18}\,\mathrm{cm}^{-2}$. Profiles from the other ro-vibrational species are also well modeled with Keplerian rotation rather than outflow, although a few exceptions are known (see chapters by J. Carr and S. Brittain).

In contrast to the paucity of outflow signatures from infrared ro-vibrational lines from the inner disk, evidence for winds is seen in the ultraviolet electronic transitions of $H_2$, pumped by broad Ly$\alpha$ emission. In a STIS study of a small number of accreting T Tauri stars Herczeg *et al.* (2006) find some stars with FUV $H_2$ profiles centered on the stellar velocity, consistent with origin from the warm inner disk surface, while others have centroids blueshifted by 10-30 $\mathrm{km\,s^{-1}}$. These profiles are shown in Figure 1, where it can be seen that several of the stars also have blue emission wings up to $\sim$ -100 $\mathrm{km\,s^{-1}}$. Similarly, in a GHRS study with lower quality data, Ardila *et al.* (2002a) found that the mean $H_2$ velocity for accreting T Tauri stars was negative, suggesting a wind contribution was present among stars in that sample as well.

The utility of the FUV $H_2$ transitions as tracers of winds is not fully understood. They are sensitive to far smaller quantities of hydrogen than the $H_2$ ro-vibrational lines formed in the outer disk and they require temperatures prior to fluorescence of T$\sim$ 2500K. Herczeg argues that at least some of the blueshifted gas must be close to the

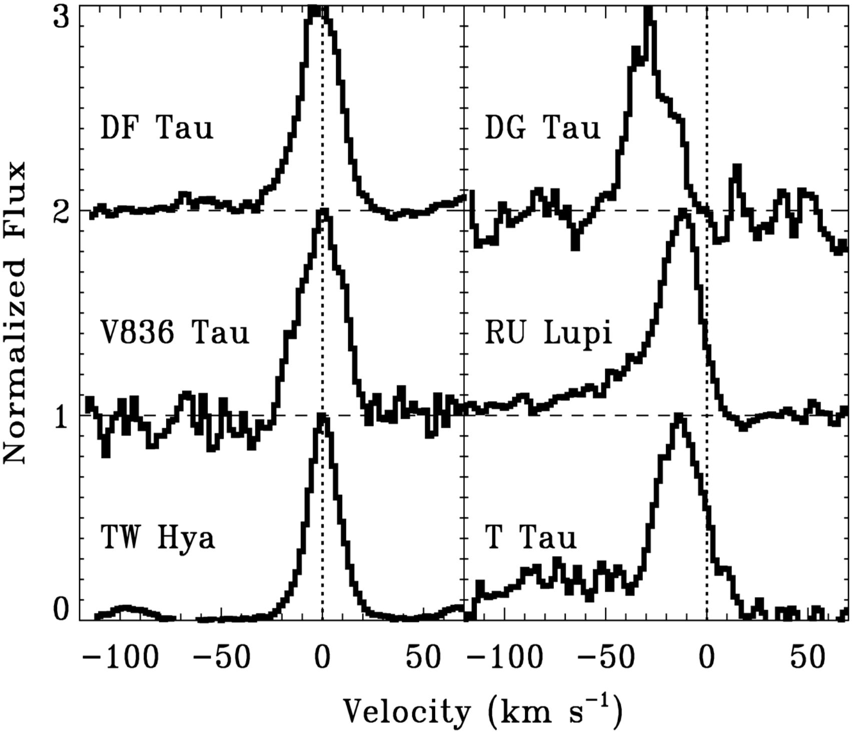

**Figure 1.** Summed FUV $H_2$ profiles for 6 accreting TTS, co-added from upper levels ($\nu = 0$ $J = 1$), ($\nu = 0$ $J = 2$), and ($\nu = 2$ $J = 12$), adapted from Herczeg *et al.* (2006) by G. Herczeg. Stars in the left panel show profiles suggesting formation in the disk, stars in the right panel have blueshifted centroids and wings suggesting formation in a wind. Zero velocity corresponds to the rest velocity of the star.

accretion flow/inner wind in order for pumping to occur over the full range of the Ly$\alpha$ profile, as required by the observed transitions. While this cannot clarify precisely where the outflowing $H_2$ originates, the bulk of the emission is at velocities reminiscent of the low velocity components seen in spatially extended forbidden lines. Thus it is tempting to say that they trace the base of a disk wind, although why this would be seen in only some of the accreting stars is not clear.

## 4. High velocity winds from the star/disk interaction zone

The spectra of accreting T Tauri stars between 0.1-2$\mu$ are shaped by the flow of mass and the transfer of angular momentum in the complex region where the magnetic fields of the star and the disk encounter each other. Our uncertainty regarding the launching process for high velocity winds comes from the challenge of deciphering the bewildering array of profile morphologies displayed by lines formed with simultaneous contributions from the funnel flow, the accretion shock, the high velocity wind, and probably other activities as well. The strength and character of line profiles and the variety of observed excitation energies and ionization states are determined in large measure by the magnitude of the disk accretion rate. Temporal variations are also a factor, arising both from rotating non-axisymmetric magnetic structures and variations in the disk accretion rate, although the magnitude of the variations displayed by an individual star are typically small compared to those arising from factors of 100-1000 in accretion rate characterizing the T Tauri class (see chapter by S. Alencar). The empirical milestones in understanding T Tauri spectra have thus either been observational programs that characterize how stars behave over the full spectrum of accretion rates or those that devote intensive synoptic monitoring to one or a few stars, each yielding valuable but very different insight.

Blue absorption signifying high velocity winds has long been recognized in the strong emission lines of H$\alpha$, Na D, Ca II H&K, and MgII h&k (Mundt 1984), although it assumes a variety of shapes and it is not present in all stars. At least for H$\alpha$, both emission and absorption (when present) equivalent widths scale roughly with the mass accretion rate verifying these phenomena are accretion-powered (Alencar & Basri 2000). The higher Balmer lines rarely show absorption from the wind, but their emission breadths are comparable to H$\alpha$ and they also often show redshifted absorption (Edwards *et al.* 1994). These profiles are usually attributed to formation in magnetospheric funnel flows (Muzerolle, Calvet & Hartmann 2001) with the exception of the blue absorption which is assumed to arise in a wind exterior to the accretion region. Simultaneous optical and ultraviolet spectra reveal that the general morphology of the NUV MgII h&k profiles is similar to H$\alpha$, both in the width of the emission and the velocity of the blueshifted absorption, although deeper absorptions in the Mg II lines indicate that this line samples larger volumes of the wind compared to H$\alpha$ (Ardila *et al.* 2002b). Evidence that some of the hydrogen emission may arise in outflowing rather than infalling gas includes both spectrophotometry showing spatial extension in Paschen lines (Whelan *et al.* 2004) and large blue emission asymmetries in wings of various H lines (Folha & Emerson 2001; Beristain, Edwards & Kwan 2001, hereafter BEK).

The remaining metallic emission lines in the optical, which can be quite numerous in high accretion rate stars, almost never show absorption from a wind, but often have a two-component morphology to their emission, with a broad component that could arise in the funnel flow or a wind plus a narrow component that is likely from the accretion shock (Batalha *et al.* 1996; Beristain, Edwards & Kwan 1998). In contrast to the metallic lines in the optical, a STIS FUV study of the high accretion rate TTS RU Lup (Herczeg *et al.* 2005) revealed numerous neutral and singly ionized metallic lines with a clear P Cygni character, with blue absorption velocities from $-70$ to $-200\,\mathrm{km\,s^{-1}}$, in some cases penetrating the continuum. Ultraviolet lines with blue absorption from winds also include some with high excitation, up to at least CII, suggesting that some outflowing gas possesses temperatures of 10,000-30,000 K (Dupree *et al.* 2005; Johns-Krull & Herczeg 2007). In addition to P Cygni profiles, recent HST STIS+GHRS spectra of the accreting T Tauri star RY Tau shows blueshifted emission in semi-forbidden and forbidden lines of Si III], C III], and [O II] with small emitting volumes suggesting formation close to the star (Gomez de Castro & Verdugo 2007).

There is thus clear evidence for the presence of high velocity winds emerging from the star-disk interaction zone, although the less well studied ultraviolet appears to offer a richer variety of probes of the outflowing gas. The best studied optical lines can be complex and hybrid nature and difficult to interpret. Synoptic studies in a few low accretion rate stars suggest simple phased relations between infalling and outflowing gas (see chapter by S. Alencar), however among stars with high disk accretion rates synoptic data show chaotic behavior (Johns-Krull & Basri 1997) that provide no clue as to whether winds are launched from the inner disk, the X-point, or the star.

### 4.1. *Tracing the inner wind with helium lines*

A surprising new diagnostic of the inner wind region in accreting stars has the potential to break through the ambiguity in determining where winds are launched in the star/disk

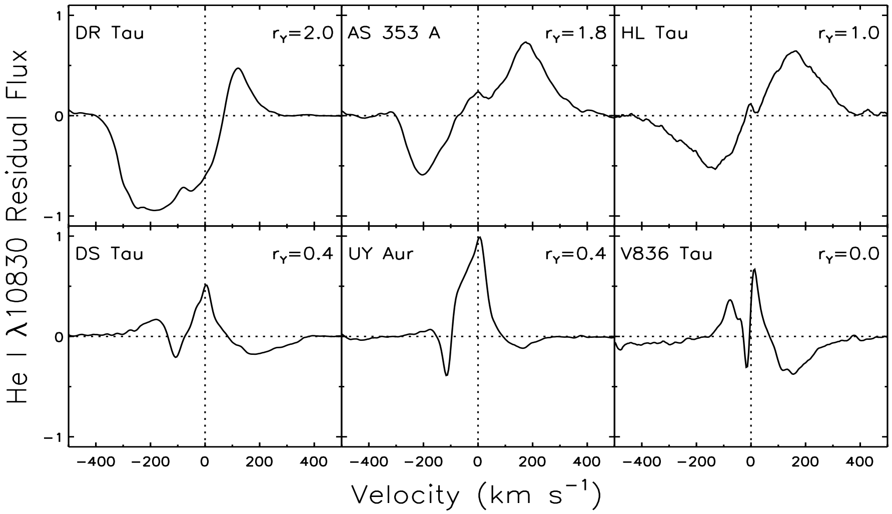

**Figure 2.** Illustration of the extremes of blueshifted absorption shown in He I $\lambda$10830 profiles of accreting TTS. The upper row shows P Cygni-like profiles with deep and broad blue absorption and the lower row shows examples of narrow blue absorption. The latter profiles also show red absorption from magnetospheric accretion columns. Simultaneous 1$\mu$ veiling, $r_Y$, is identified for each star.

interaction region. This is He I $\lambda$10830, falling in a wavelength regime only recently available to high dispersion spectrographs on large telescopes. A survey of 38 accreting T Tauri stars spanning a wide range of disk accretion rates shows that He I $\lambda$10830 has a far higher incidence of P Cygni profiles than any other line observed to date (Edwards *et al.* 2006), often with a velocity structure reminiscent of the spherical stellar wind models of Hartmann *et al.* (1990). Blueshifted absorption below the continuum is found in ~70% of the stars, in striking contrast to H$\alpha$ where the fraction is ~10%. In some stars the blue absorptions display remarkable breadth and depth, where 90% of the 1$\mu$ continuum is absorbed over a velocity interval of 300-400 km s$^{-1}$, while others show narrow absorption with modest blueshifts, as illustrated in Figure 2. The extraordinary potential for He I $\lambda$10830 to appear in absorption derives from the high opacity of its metastable lower level ($2s^3S$), $\sim$ 21 $eV$ above the singlet ground state, which becomes significantly populated relative to other excited levels owing to its weak de-excitation rate via collisions to singlet states. There is no question that the inner wind probed by He I $\lambda$10830 derives from accretion, since it is not seen in non-accreting T Tauri stars and the strength of the combined absorption and emission correlates with the excess continuum veiling at 1$\mu$.

The He I $\lambda$10830 profiles offer a unique probe of the geometry of the inner wind because this line is formed under conditions resembling resonance scattering, with only one allowed exit from the upper level and a metastable lower level. Thus it will form an absorption feature via simple scattering of the 1 $\mu$ continuum under most conditions. Any additional in-situ emission is modest in comparison to lines like $H\alpha$, which have net emission equivalent widths 10-100 times greater than He I $\lambda$10830 (Edwards *et al.* 2003). Moreover, the helium lines are restricted to form in a region of either high excitation or close proximity to a source of ionizing radiation, which is likely to be within the crucial 0.1 AU of the star where the inner high velocity wind is launched.

A recent study takes advantage of these sensitivities to model helium profile formation using Monte Carlo scattering calculations for two inner wind geometries: a disk wind emerging at a constant angle relative to the disk surface and a stellar wind emerging radially away from the star (Kwan, Edwards, & Fischer 2007). The specific configuration of the X-wind has not yet been explored as the flow geometry is currently being revised in order to take into account the interaction between the stellar and the disk field (see chapter by F. Shu). Both stellar and disk wind geometries were parameterized with a simple set of assumptions that allowed a variety of effects to be explored. For the disk wind, launching was confined between 2-6 $R_*$ since helium excitation is unlikely to persist at great distances, and angular velocities along streamlines maintained either rigid rotation or conserved angular momentum. The stellar wind was assumed to originate between 2-4 $R_*$, both spherical and polar geometries were examined, and the effects of disk shadowing were explored. The latter ranged from extreme (disk truncation radius inside the wind origination radius) to negligible (disk truncation radius $\geqslant 5$ times the wind origination radius). In each case, profiles were computed under the assumption of pure scattering, where all the $1\mu$ continuum photons were assumed to come from the star, and also with the additional presence of in-situ emission.

The resulting suite of profiles show morphologies resembling the variety found in the data. One key difference between stellar and disk wind profiles is the breadth of velocities in the blue absorption feature. For a stellar wind, any line of sight to the star will intercept radial velocities corresponding to the full acceleration in the wind, giving rise to very broad blue absorptions, such as in the upper panel of Figure 2. For the disk wind however, a particular line of sight to the star will intercept line-of-sight velocities over a narrow interval, and the centroid of the narrow absorption will have a large or small blueshift, depending on the view angle to the star and the opening angle of the wind, as in the lower panel of Figure 2. Among the full sample of 38 accreting T Tauri stars there are roughly comparable numbers with blue absorptions resembling disk (30%) or stellar (40%) winds.

Another distinguishing characteristic between stellar and disk winds is the morphology of the emission component above the continuum. For stellar winds a range of emission morphologies are possible, depending on whether they are dominated by scattering or in-situ emission (which can fill in the blue absorption at low velocities), and whether disk shadowing is important. For the disk wind, however, emission from scattering would be spread out over such a range of velocity that it would appear very weak, while in-situ emission would either be entirely blueshifted or broad and double-peaked, depending on the view angle. Among the stars in the survey, none show He I $\lambda10830$ emission resembling the expectation for disk winds, implying that scattering is the only process forming helium lines in the disk winds. In contrast, most of the profiles show emission morphologies expected for stellar winds, including some of those with blue absorptions resembling disk winds. For the stars in Figure 2, the 3 in the top panel with blue absorptions resembling stellar winds all have net equivalent widths $\leqslant 0$, indicating that scattering is the dominant formation mechanism, and one of these, DR Tau, has quite a large net negative equivalent width, which is explained if the disk truncation radius is smaller than the wind origination radius. The 3 in the bottom panel with blue absorptions resembling disk winds all show helium emission as well as redshifted helium absorption from the funnel flow. Some of the emission will thus be from scattering in the funnel flow, while the rest may be from a polar stellar wind viewed at a large angle.

The restricted excitation conditions for He I $\lambda10830$ and its resonance scattering properties make it an unprecedented diagnostic of both winds and funnel flows in the star/disk interaction region, providing the first opportunity to diagnose wind geometries in stars

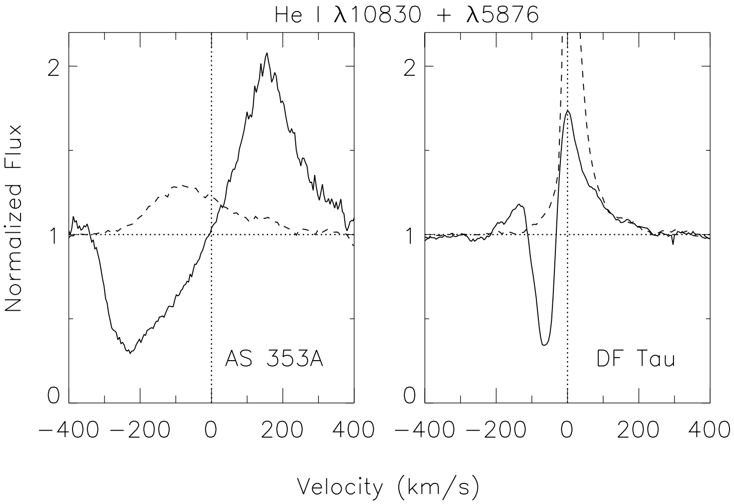

**Figure 3.** Simultaneous profiles for He I $\lambda10830$ (solid) and He I $\lambda5876$ (dotted) for two accreting T Tauri stars.

spanning nearly 3 orders of magnitude in disk accretion rates. In § 5 we suggest that while both disk and stellar winds are likely present in most accreting stars, the variety of observed He I $\lambda10830$ profiles probably results both from viewing star/disk systems over a range of angles and from an alteration in the geometry of the magnetospheric configuration between high and low accretion rate T Tauri stars.

### 4.2. *Wind energetics and mass loss rates*

Although there are a variety of atomic lines with spectroscopic signatures of high velocity winds formed in the inner 0.1 AU of accreting T Tauri stars, we have very limited quantitative information on the wind energetics. Recent attempts to model $H\alpha$ profiles suggest that a disk wind may be the source of the narrow blue absorptions often seen in this line (Alencar *et al.* 2005; Kurosawa *et al.* 2006). However, extracting mass loss rates from a hybrid line such as $H\alpha$ is difficult. From the frequent presence of blue absorption at H$\alpha$ and its almost total absence in the higher Balmer lines Calvet (1997) estimated optical depths and temperatures of the wind, leading to $\dot{M}_w \sim 10^{-8}$ M$_\odot$ yr$^{-1}$ for some of the high accretion rate stars. Ideally this would be compared with mass loss rates determined from forbidden lines to assess whether the bulk of the material in the more distant collimated jet (Hartigan, Edwards & Ghandour 1995) is carried by the high velocity wind seen at H$\alpha$. Unfortunately uncertainties in these values are currently too large for any meaningful comparison.

The He I $\lambda10830$ line seems to be penetrating the obscurity regarding the launch region, but by itself it is not a strong diagnostic of physical conditions in the wind. However, at least for the restricted region where He I $\lambda10830$ is excited and can scatter $1\mu$ continuum photons, mass loss rates from both the stellar and disk winds will be able to be determined from comparison of He I $\lambda10830$ and its immediate precursor in a recombination/cascade sequence, He I $\lambda5876$. Although the kinematic properties of He I $\lambda5876$ are quite different from its near infrared sibling (appearing entirely in emission with kinematic properties that vary among stars, see BEK), this pair of lines have intimately coupled excitation conditions that will enable the relative contribution between continuum scattering and in-situ emission to be evaluated for He I $\lambda10830$ and the corresponding physical conditions, including line opacities, electron densities, kinetic temperatures, and limits on the ionizing flux, to be assessed.

In order to determine mass loss rates from this powerful pair of lines, simultaneous optical and near infrared spectra have been obtained with Keck's NIRSPEC + HIRES by L. Hillenbrand, S. Edwards and W. Fischer, and statistical equilibrium calculations for a 19-level helium atom and 6-level hydrogen atom have been made by J. Kwan. This work is in preparation, but examples of simultaneous profiles for two accreting T Tauri stars are shown in Figure 3. For AS 353 A, He I $\lambda10830$ shows a stellar wind profile that includes contributions from both scattering and in-situ emission. At the same moment, He I $\lambda5876$ shows blueshifted emission, arising from in-situ emission in the wind. In contrast, for DF Tau, He I $\lambda10830$ shows blue absorption formed by scattering in a disk wind, while both helium lines show in-situ emission from an accretion shock and redshifted infalling gas in the funnel flow. The absence of narrow He I $\lambda5876$ emission from an accretion shock is also found in other stars with strong stellar wind signatures and high accretion rates, suggesting that the size and/or geometry of the funnel flow is altered when disk accretion rates are high (BEK).

## 5. Multiple inner high velocity winds?

A mix of stellar and disk wind profiles in He I $\lambda10830$ would arise naturally if stellar winds emerge primarily from polar regions, inner disk winds are also present, and both are close enough to the star/accretion shock for helium to be excited either through ionization/recombination or (less likely) collisional excitation. Whether the blue absorption resembles a stellar or disk wind would depend on inclination, but emission from the stellar wind could be seen at any orientation. Inclination may thus be the explanation for the He I $\lambda10830$ profiles for two low accretion rate stars with well determined inclinations: TW Hya, nearly nearly pole-on (Dupree *et al.* 2005) has a stellar wind profile formed via scattering and in-situ emission, while AA Tau, nearly edge-on (Bouvier *et al.* 2007), shows blue absorption from a disk wind plus emission that could be from a polar stellar wind, along with red absorption from a funnel flow. Uncertainties in published inclinations can be large, but among the stars with blue absorptions resembling disk winds values range from $40^o$-$80^o$, providing some support for the expectation that disk wind profiles in He I $\lambda10830$ are favored in more edge-on systems (Kwan, Edwards, & Fischer 2007). There is also a tendency to see redshifted absorption from funnel flows preferentially in the stars with disk wind profiles, which would also be favored in systems seen at larger inclinations.

In addition to inclination, the disk accretion rate also seems to be a factor in determining the observed morphology. Among the most heavily veiled stars in the Edwards *et al.* survey ($r_Y \geqslant 1$), neither disk wind or magnetospheric infall absorptions are seen at He I $\lambda10830$. Instead this group contains the clearest cases for stellar wind profiles (e.g. top panel of Figure 2) and also includes emission profiles with no subcontinuum absorption, as might result from a polar stellar wind seen edge on without any intervening absorption from the disk wind. The rarity of infall signatures for stars with high veiling suggests that the funnel flow may be reduced in size, as might result from a decrease in the disk truncation radius under the pressure of high disk accretion rates, or possibly there is a more drastic reconfiguration of the basic funnel flow geometry (see chapter by M. Romanova). Whatever the cause, the He I $\lambda10830$ profiles suggest that conditions for driving winds radially outward from the star are favored when disk accretion rates are high. Additional support for this line of reasoning is provided by $H\alpha$ profiles in some of the highest accretion rate systems such as AS353A and DR Tau, which show P Cygni structure resembling predictions for stellar winds (see Edwards *et al.* (2003)). In fact it was such $H\alpha$ profiles from a few of the brightest T Tauri stars that gave rise to the idea of stellar winds so many decades ago.

## 6. The future

The evidence to date suggests that it is oversimplified to imagine that accretion powered winds have a single origin. The question instead becomes "Which of the various means of launching winds from accreting systems is most influential in spinning down the star, in extracting angular momentum from the disk, and in feeding the extended jets and molecular outflows?" Ultimate understanding of the accretion/ejection connection will certainly require multiple lines of inquiry, but eventually the phenomenon Bertout (1989) called "The Twilight Zone" will be elucidated.

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