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ACCRETION AND OUTFLOW FROM YOUNG STARS

Patrick Hartigan
Department of Space Physics and Astronomy, Rice University
PO Box 1892. Houston, TX 77251-1892, USA
and
Suzan Edwards and Louma Ghandour
Five College Astronomy Department, Smith College
Northampton, MA, USA

RESUMEN

En este trabajo comparamos las tasas de acreción y pérdida de masa determinadas para 42 estrellas T Tauri distribuídas en un amplio intervalo de excesos infrarrojos. Las tasas de acreción de masa se obtuvieron a partir de mediciones del exceso en el continuo presente en espectros ópticos de alta resolución y las tasas de flujo de masa provienen de las estimaciones de la luminosidad de la componente de alta velocidad de la línea en emisión de [O I] λ6300. La mayoría de las estrellas de nuestra muestra tienen tasas de acreción del orden de $10^{-6} - 10^{-8}$ $M_{\odot}$ por año y tasas de pérdida de masa entre $10^{-8} - 10^{-10}$ $M_{\odot}$ por año. Nuestros resultados muestran la primera relación directa entre acreción y flujo. El cociente entre la tasa de pérdida de masa y la tasa de acreción depende de cómo se interpreta la luminosidad de las líneas prohibidas, pero probablemente es del orden de 0.01 para la mayoría de las estrellas T Tauri clásicas.

ABSTRACT

In this poster we compare mass accretion and mass outflow rates determined for 42 T Tauri stars that span a broad range of infrared excesses. The mass accretion rates are derived from measurements of the excess continuum present in high resolution optical spectra, and the mass outflow rates come from estimates of the luminosities of the high velocity component of [O I] λ6300 emission. Most of the stars in our sample have mass accretion rates $\sim 10^{-6} - 10^{-8}$ $M_{\odot}$ yr^{-1}, and mass loss rates $\sim 10^{-8} - 10^{-10}$ $M_{\odot}$ yr^{-1}. Our results demonstrate the first direct relationship between accretion and outflow. The ratio of mass outflow rate to the mass accretion rate depends upon how the forbidden line luminosities are interpreted, but is probably ~ 0.01 for most classical T Tauri stars.

Key words: **ISM: GENERAL — LINE: PROFILES — STARS: MASS-LOSS — STARS: PRE-MAIN SEQUENCE**

1. OVERVIEW

This poster summarizes a portion of a paper that has been submitted recently to ApJ (Hartigan, Edwards, & Ghandour 1995). Over the past six years we have observed a total of 42 young stars in the Taurus and Orion dark clouds with the echelle spectrograph on the 4-m telescope at Kitt Peak National Observatory. The observations have a spectral resolution of $\sim$ 12 km s^{-1}, and cover a wavelength range from about 5000 Å to 6800 Å. One of the primary goals of the project is to relate accretion and outflow phenomenon in the earliest phases of stellar evolution.

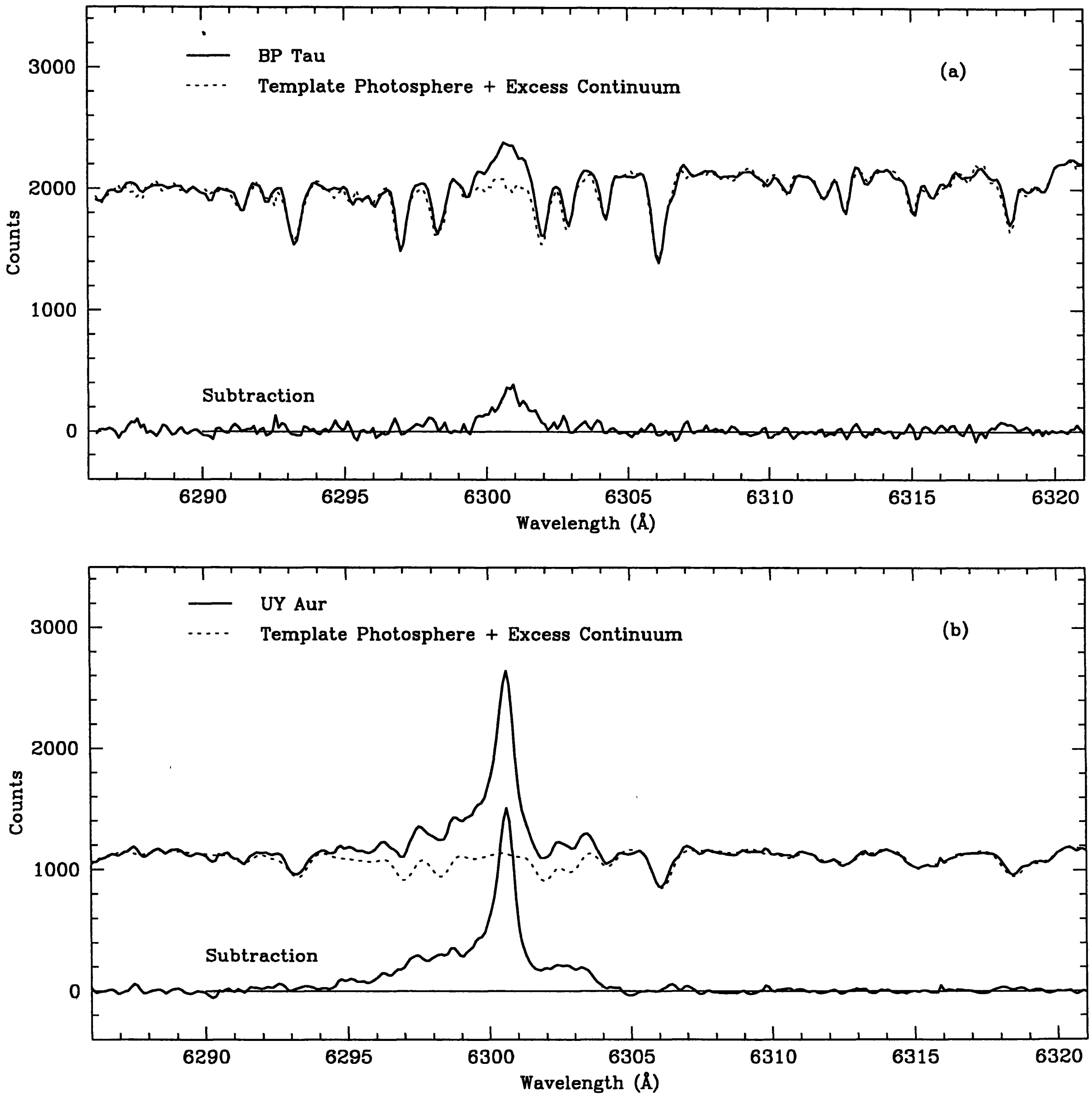

Fig. 1. (a): A portion of the spectrum of BP Tau that includes the line [O I] λ6300. The observed spectrum of BP Tau (top, solid line) shows a weak emission line superimposed upon several photospheric absorption lines. A model of the photospheric lines and continuum of BP Tau appears as a dotted line. The model consists of the sum of a flat continuum and the spectrum of a template T Tauri star with no excess emission (Lk Ca7). The difference between the observations and the model appears at the bottom of the plot, and clearly shows the [O I] λ6300 emission line profile of BP Tau. The spectral resolution is 12 km s^{-1} (0.25 Å). (b): The observed spectrum, model fit, and subtraction for UY Aur. The residual forbidden line profile shows broad redshifted and blueshifted wings, which we use to estimate mass loss rates.

2. MASS ACCRETION RATES

Young stars often show blue continuum excesses at optical wavelengths that are thought to arise from a boundary layer or hot spots formed as material from a circumstellar disk accretes onto the star (Kenyon & Hartmann 1987; Bertout 1989). We can measure mass accretion from the amount of excess continuum present

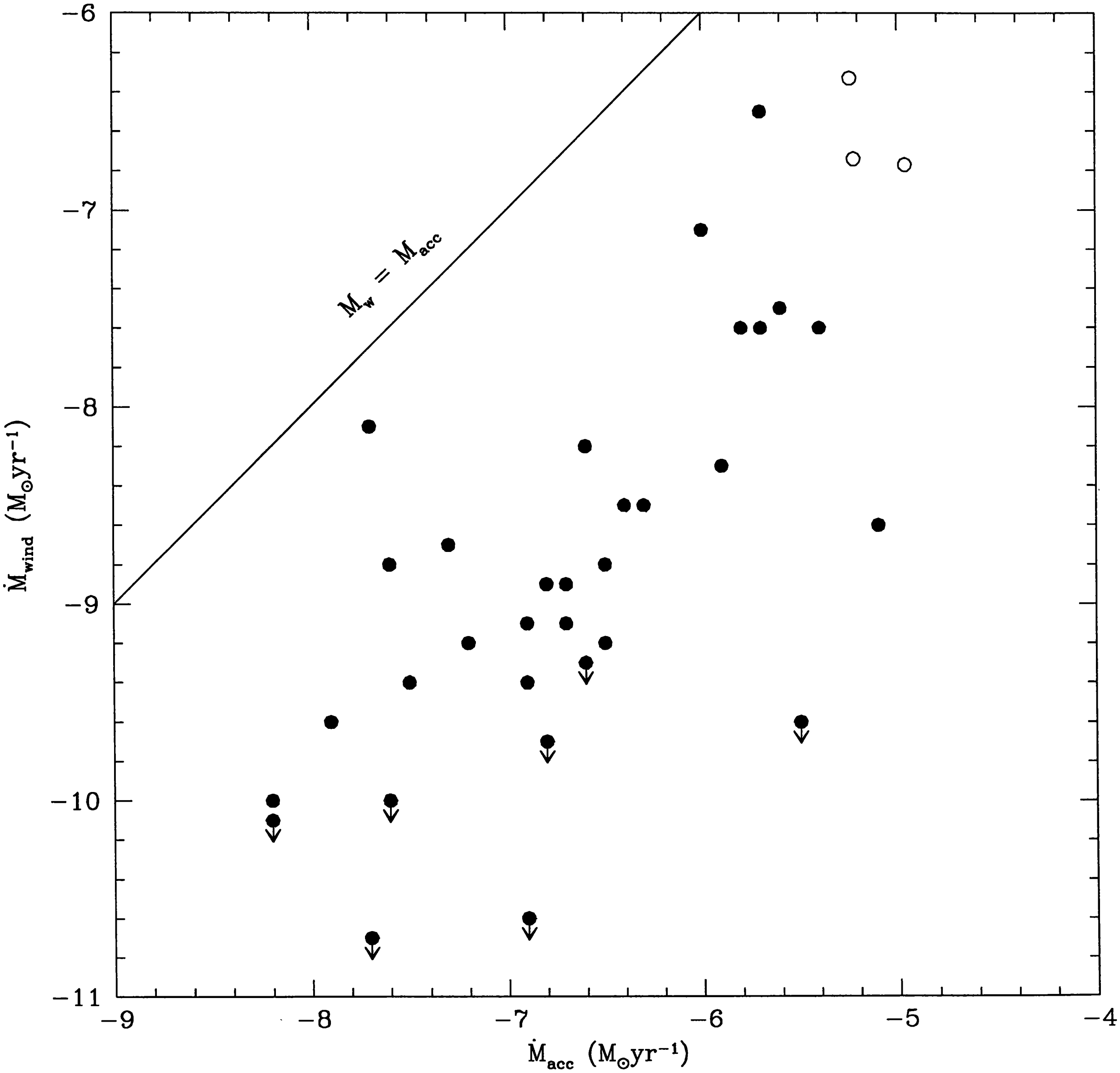

Fig. 2. The mass loss rate plotted against the mass accretion rate for our sample of T Tauri stars. A correlation exists between the two rates, with $\dot{M}_w/\dot{M}_{acc} \sim 10^{-2}$ for most stars. The three open circles represent the prominent stellar jets HH 34, HH 47, and HH 111 (Hartigan, Morse, & Raymond 1994).

in the spectra of T Tauri stars (Hartigan et al. 1991). Observationally, we can define a parameter 'r' as the ratio of the continuum excess to the photospheric flux. The r-values as a function of wavelength are determined by comparing the depths of photospheric absorption lines in T Tauri stars with photospheric lines in stars that lack excesses. Stars with large r-values accrete more rapidly and have correspondingly shallower absorption lines (because of the strong excess continuum) than do stars with low r-values.

We can easily convert the observed r-value and V magnitude of the entire object into V magnitudes for the star and boundary layer separately. Then the luminosity of the boundary layer L_{bl} is given in terms of the r-values and bolometric corrections for the star and boundary layer by the expression (see Hartigan et al. 1995 for details)

$$log\left(\frac{L_{bl}}{L_*}\right) = 0.4\,[V_* - V_{bl} + BC_V(*) - BC_V(bl)] = log\,(2r_V) + 0.4\,[BC_V(*) - BC_V(bl)]\,. \qquad (1)$$

The mass accretion rate is

$$\dot{M}_{acc} = \frac{2L_{bl}R_*}{GM_*} = 6.36\times10^{-8}\left(\frac{L_{bl}}{L_\odot}\right)\left(\frac{M_*}{M_\odot}\right)^{-1}\left(\frac{R_*}{R_\odot}\right)\ M_\odot\ yr^{-1}. \qquad (2)$$

3. MASS OUTFLOW RATES

Forbidden emission lines in T Tauri stars have two distinct components, a high velocity component that resembles a stellar jet, and a low velocity component of uncertain origin (Hamann 1994). To calculate accurate mass outflow rates from young stars we must separate emission in the outflow from that of the low velocity gas. To isolate the high velocity emission lines we first subtracted the photospheric, excess, and terrestrial components of the spectrum to leave only a residual emission line profile of [O I] λ6300 (see Figure 1). The residual emission line luminosity at velocities greater than $\pm$60 km s^{-1} is proportional to the mass loss rate in the flow. The appropriate equation for stars at the distance of the Taurus dark cloud is

$$log_{10}\dot{M}_w = -4.30 + log_{10}\left(\frac{L_{6300}}{L_\odot}\right), \qquad (3)$$

where $\dot{M}_w$ is measured in $M_\odot$ yr^{-1}.

There are several different ways to measure mass loss rates in jets, and although the mass loss rate is proportional to the line luminosity in all cases, the proportionality constant can vary by two orders of magnitude depending on the method used. Thus, the numerical value of the mass loss rate is quite uncertain, but any correlations between mass accretion and mass outflow should be independent of the models.

4. RESULTS

A plot of the mass loss rates and mass accretion rates in Figure 2 reveals a clear correlation between the mass accretion and mass outflow rates, the first *direct* correlation between these two quantities. The ratio between mass accretion and mass outflow rates is $\sim$ 0.01 in this figure.

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