MASS LOSS IN T TAURI STARS: OBSERVATIONAL STUDIES OF THE COOL PARTS OF THEIR STELLAR WINDS AND EXPANDING SHELLS

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Extensive high resolution ($\Delta V = 12$ km s^{-1} FWHM) and high S/N profile measurements of 25 T Tauri stars have been obtained using the Arizona/Smithsonian Multiple Mirror Telescope echelle spectrograph, and photon counting Reticon. In order to investigate the cooler regions of these stars expanding envelopes, most of the profiles were of the Na D lines. Indications of mass loss in the Na D (and Ca II H and K) lines have been found in 11 stars. These stars show considerably stronger permitted and forbidden emission lines than the stars with negative detections. These 11 stars seem to belong to the high mass loss T Tauri stars. There high density winds are expected to cool very efficiently by radiation cooling and thus making there winds observable in Na D or Ca II H and K. In 8 of these 11 stars the blueshifted absorption observed in the Na D lines were surprisingly narrow ($10 \leq$ FWHM≤ 50 km s^{-1}), and were in some cases not variable in radial velocity over up to two years ($\Delta V \lesssim 3$ km s^{-1}). The data strongly suggest that, in *some* stars, the observed sharp, blueshifted absorption originates in an extended cold shell. The estimated lower limit for the radius of the shell in various stars ranges from 10-40 AU, but might actually be considerably larger. The presence of extended shells might be correlated with recent outbursts of these stars. The observations suggest that the stars with narrow blueshifted absorptions in the Na D (and Ca II H and K) lines have terminal wind velocities of 100-150 km s^{-1}. Variations in T Tauri star wind properties over a wide range of time scales (weeks to decades) seem to be present. A new interpretation of the YY Orionis phenomenon is suggested on the basis of these new data. The descending material occasionally observed in some T Tauri stars is interpreted to be infalling matter recently ejected by these stars, and not matter left over from the star formation process.

A very detailed discussion of these observations has been submitted by *Ap. J.*

DISCUSSION

Carrasco: I fully agree with your interpretation on the wind driven circumstellar shells origin of the narrow blueshifted components. Furthermore, S CrA shows the same phenomenon in the Ca II H and K lines, the blue-shifted absorption component has slowed down by about 20 km s^{-1} during the last 20 years.

Mundt: I got the same results using both the Ca II H and K lines and the Na D line results of various previous studies. There seems to be little difference in the Ca II and Na D absorption profile (as far as we can tell by comparing spectra of different resolution).

Rydgren: Do you see such absorption features in less extreme T Tauri stars?

Mundt: No. Such absorption features were found in a "weak" emission line T Tauri star ($W_\lambda \leq 25$ A). Of course there is a broad spread in the properties of both groups. But as mentioned, the stars with blue absorptions had, on the average, much stronger emission lines (W_λ(Hα) on the average 90 A) and stronger veiling.

Montmerle: Can you determine physical parameters such as N_e or T_e in the absorbing, as well as in the emitting, regions?

Mundt: This would require radiative transfer calculations in the various lines which I have not yet done. I want to mention only that the strength of some of the observed absorption features are consistent with a stellar wind of $\dot{M} \simeq 10^{-8}$ $M_\odot$/yr which is colder than about $T \leq 5000$ K at large distance from the star (e.g., 20 $R_\star$) and with the ionization of Na D dominated by stellar radiation from the T Tauri star.

Calvet: Is there a relation between the Na I absorption line strength and the strength of the fluorescent emission lines of Fe I, which supposedly are formed in the extended region by absorption of He from the star?

Mundt: I have not looked into that.

Kuhi: How did you get the 10 AU and 40 AU distances for the shell?

Mundt: Simply by multiplying their "stability times" (2 years for DR Tau) by the shell velocity ($\simeq$ 100 km s^{-1} for DR Tau).

Ambartsumian: Have you noticed any correlation of the intensity of blue-shifted absorption components and such properties of T Tauri stars as the amplitude and time scale of variations or the presence of ultraviolet or continuous emission?

Mundt: I have not looked in detail on a correlation between variability and the presence of any blue shell absorption feature in these stars, but it appears that in general they have higher variability. It is especially noticeable that two of these stars (namely UZ Tau and DR Tau) had recent outbursts in their brightness. DR Tau brightened in 1970 by 3 mag and is still in its enhanced brightness phase.