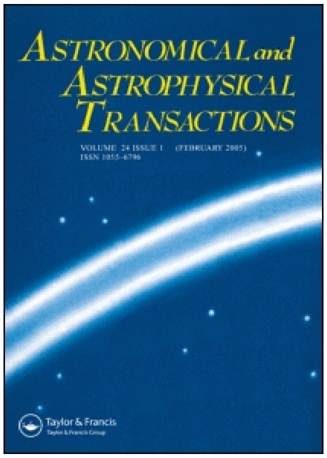

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UV SPECTRA OF T TAU STARS FROM HUBBLE SPACE TELESCOPE

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HST/GHRS spectra of 5 classical T Tau stars (CTTSs) in the 1150–2800 spectral band were analyzed in detail for the first time. Profiles of optically thin Si III] 1892 and C III] 1909 lines in RU Lup and RY Tau spectra are asymmetric and have FWHM > 100 km s^{-1} which definitely excludes their origin in chromospheric regions. It appeared possible to reproduce observed profiles in the framework of an accretion shock model. A flare-like event was detected in the case of RY Tau accompanied with a redshift of CIV 1550 and He II 1640 line profiles. A number of strong lines of molecular hydrogen were found: they originated in CTTS circumstellar envelopes and L_α quanta pumped by accretion shock. CTTSs L_α luminosity can reach 10% of the observed bolometric luminosity. It is shown that Fe II absorption lines originating in CTTS stellar wind along with H_2 emission lines can significantly disturb profiles of C IV 1550 and Si IV 1400 lines. We also found Fe II fluorescent emission lines in RW Aur and BP Tau spectra originating in stellar wind and also pumped by L_α.

KEY WORDS T Tau stars, accretion process, stellar wind, stars – individual: BP Tau, DF Tau, RU Lup, RW Aur, RY Tau

1 INTRODUCTION

It is widely assumed now that the activity of CTTSs is due to disk accretion onto a magnetized low mass young star. But there are clear indications that CTTSs also have strong stellar wind and coronal regions with a gas temperature T$\sim 10^7$ K – see e.g. review of Najita *et al.* (2000) and references therein. To determine the physical conditions and geometry of these regions it is necessary to separate the contribution of accretion shock, stellar wind and chromospheric regions into the CTTSs observed spectrum. It appears impossible to do this by analysing optical spectra only.

The aim of this presentation is to demonstrate the main results of UV spectra analysis of 5 CTTSs observed with HST Goddard High Resolution Spectrograph (GHRS) from 1992–1996: RU Lup (Lamzin, 2000a), RY Tau (Lamzin, 2000b), RW Aur (Errico *et al.*, 2000), DF Tau (Lamzin *et al.*, 2001) and BP Tau (Errico *et al.*, 2001) – the respective references are omitted in the text for brevity. The analyzed spectra were adopted from the HST Archive, recalibrated using the most

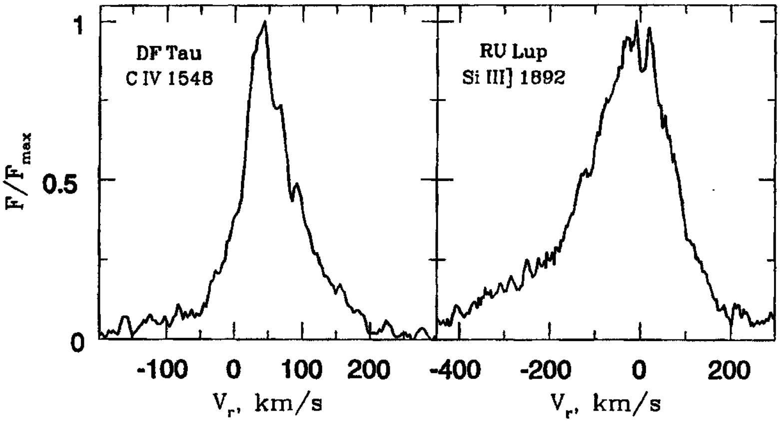

Figure 1 Normalised profiles of DF Tau C IV 1548 and RU Lup Si III] 1892 lines.

up-to-date reference files and processed with IRAF v2.11 and STSDAS/TABLES v2.0.2 software as recommended in Chap. 36 of 'HST Data Handbook'. To improve the S/N-ratio all independent exposures within each spectral band were combined and additionally smoothed via a 4-point running mean, so the resulting spectral resolution is near 15 km s^{-1}.

2 ACCRETION

Analyzed HST spectra undoubtedly indicate that emission lines of ions with charge $Z > +1$ can not originate in a stellar chromosphere – they are too wide and asymmetric – see Figure 1. We argue that they originate in the accretion flow before and behind the shock front in agreement with theoretical predictions (Lamzin, 1998). It is obvious in the case of DF Tau redshifted profile of (optically thick) C IV 1548.2 line, but it appeared also possible to reproduce the RU Lup observed profile of the (optically thin) Si III 1892 line in the framework of the accretion model assuming a non-axisymmetrical velocity field (Lamzin, 2000c).

For the average accretion rate and infall gas density N_0 we found ranges from $3 \times 10^{-9} M_\odot$/yr and 10^{11} cm^{-3} (DF Tau) to $3 \times 10^{-7} M_\odot$/yr and 3×10^{12} cm^{-3} (RU Lup). It appeared that order of magnitude variations of N_0 in the case of DF Tau were not accompanied with more or less significant variations of emission continuum intensity at $\lambda = 1900$Å. Simultaneous variability of RY Tau C IV 1550 and He II 1640 line fluxes (flare-like event) with a characteristic time of $\sim$ 20 minutes was observed. The increase of the lines' fluxes was accompanied by a redshift of the lines profile maximum up to 50 km s^{-1} – see Figure 2. Note that the C I 1657 line flux variations are much less expressed, if at all.

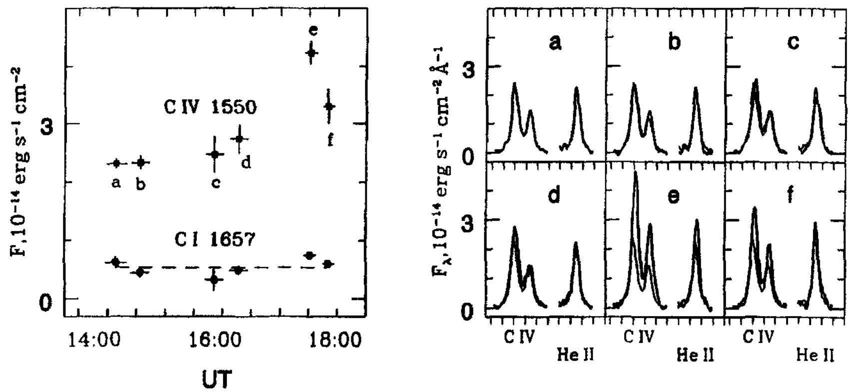

Figure 2 RY Tau flare-like event observed November,13 1994. Variations of C IV 1550 and C I 1657 lines fluxes with time (left panel) and respective variations of C IV 1550 and He II 1640 lines profiles (right panel). Initial profiles of the lines (a) are shown for b, c, d, e, f plots with thin lines for comparison.

3 STELLAR WIND

No strong *emission* lines originating in stellar wind were found in HST spectra of the investigated stars. But blueshifted absorption features are present in the blue wings of Mg II h and k lines indicating gas outflow with velocity ≥ 100 km s^{-1}, such as BP Tau which even has two blueshifted absorption features – see Figure 3. The continuum is underexposed in all the analysed spectra except near the Mg II 2800 doublet and we found Fe II uv234 multiplet lines in absorption in the respective spectra of DF Tau (inverse P Cyg profile) and RW Aur (P Cyg profile). In the case of RW Aur Fe II absorption lines are also superimposed onto C IV 1550 doublet lines significantly disturbing their observed profiles – see Figure 4. These Fe II lines originate in the gas moving away from the star but it is not clear if we are observing stellar wind or a stream of disk matter which will fall onto the star after it reaches maximal height above the stellar surface as some theories predict – see e.g. Miller and Stone (1997).

4 H I L_α RADIATION AND H_2 AND FE II FLUORESCENT LINES

A number of H_2 molecular lines are present in the spectra of all the investigated stars (except maybe RY Tau) at $\lambda < 1900$Å. These lines originate in the extended circumstellar envelops of CTTSs due to pumping of molecular gas by H I L_α quanta (Brown *et al.*, 1984; Walter and Liu, 1998). We also found Fe II fluorescent lines pumped by L_α line emission in spectra of RW Aur and BP Tau – see Figure 4.

We argue that the source of L_α emission is an accretion shock and found that in some cases CTTS L_α line luminosity can be $\sim 10\%$ of bolometric luminosity (Kurt

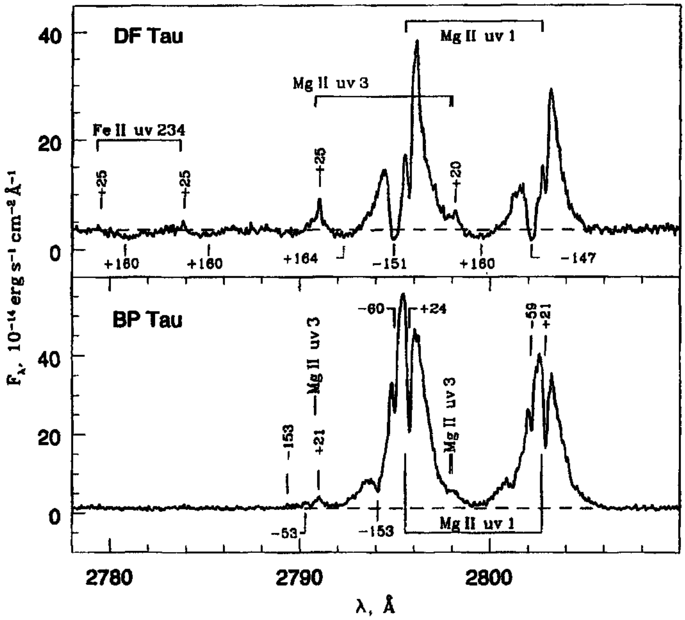

Figure 3 HST/GHRS spectra of DF Tau (top) and BP Tau (bottom) in the vicinity of Mg II h and k resonant lines. Blueshifted absorbtion features are present in h and k lines at $\Delta V \simeq -150$ km/s in addition to narrow interstellar feature near line's center. There are one more absorption feature at at $\Delta V \simeq -60$ km/s in the case of BP Tau. DF Tau subordinate Mg II uv3 multiplet lines as well as Fe II uv234 multiplet lines have inverse P Cyg. Note the velocity correspondence between emission and absorption features in different lines.

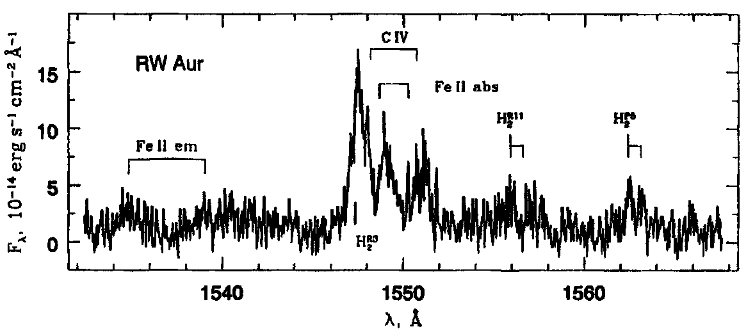

Figure 4 HST/GHRS spectrum of RW Aur. Superposition of Fe II absorption lines radically disturbs observed profiles of C IV 1550 doublet lines. One can also see fluorescent Fe II and H_2 emission lines, such as the last look double peaked.

and Lamzin, 1995). Apparently accretion shock L_α radiation plays an important role in the thermal and ionization balance of stellar wind at least at the base of the outflow. The line radiation pressure onto circumstellar hydrogen atoms can be important in the initial acceleration of stellar wind matter, but the influence of L_α radiation on the dynamics of molecular gas is negligible.

Fe II fluorescent lines originate in the stellar wind not far from the stellar surface. The dynamical status of CTTS circumstellar molecular gas is not obvious: the H_2 lines are slightly blueshifted in RU Lup spectrum, are practically at rest relative to the star in the case of DF Tau and are redshifted in the case of BP Tau. It can be seen from Figure 4 that the H_2 lines in RW Aur spectrum are even double peaked. The full width of lines at zero intensity ranges from ~ 50 km s^{-1} (RU Lup) up to 100 km/s (DF Tau).

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