MAGNETOSPHERIC PROPERTIES OF T TAURI STARS THROUGH C II], Fe II] AND Si II] ULTRAVIOLET EMISSION LINES

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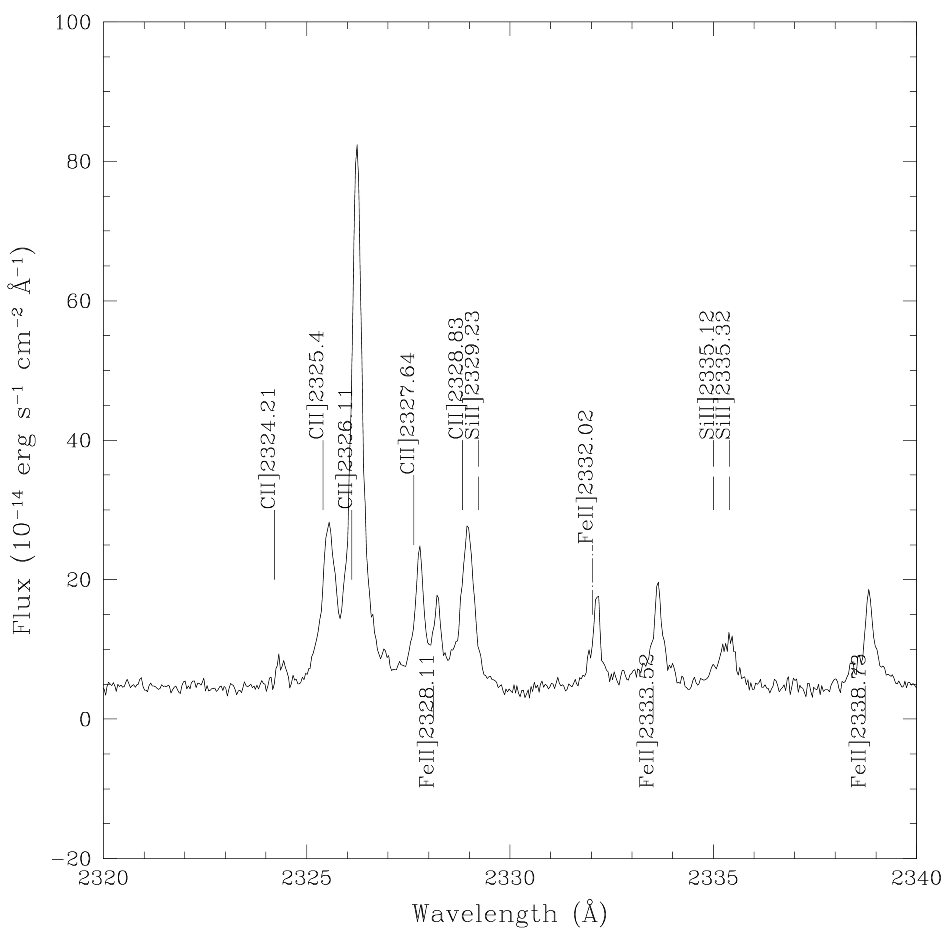
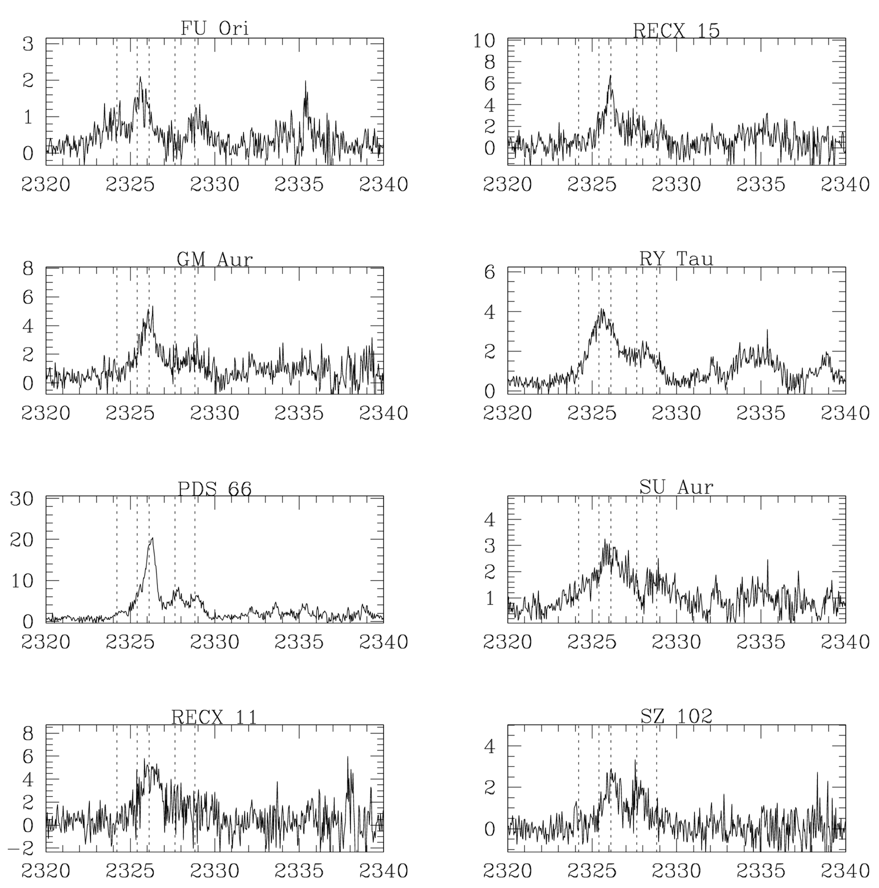
ABSTRACT: *The C II], Fe II] and Si II] semiforbidden lines are in the range 2320-2340 Å. These emission lines provide a reliable optically thin tracer for measuring the plasma properties in the magnetosphere of T Tauri stars (TTSs). In this work, these lines are analyzed in a sample of 20 TTSs using 30 medium resolution spectra from the Hubble Space Telescope (HST) data archive. We developed an algorithm in IDL making use of theoretical values of emission line ratios derived from CHIANTI to fit the observed spectra. The procedure provides the properties of the emission regions, such as electron density, temperature and line broadening. Most stars in the sample have temperatures in the range from $10^{4.1}$ to $10^{4.5}$ K and densities from 10^{8} to 10^{12} cm^{-3}. These stars have suprathermal line broadening (between 35 and 165 km/s), except TW Hya and CY Tau with thermal line broadening. Both C II] line luminosity and broadening are found to correlate with the accretion rate. Line emission seems to be produced in the magnetospheric accretion flow, close to the disk.*

1.- THE SAMPLE

The semiforbidden lines of the C II] quintuplet (wavelengths: 2324.21, 2325.4, 2326.11, 2327.64 and 2328.83 Å) are not observed in Weak line TTSs; however, they are readily detected in Classical TTSs (CTTSs), even in low mass accretors. This multiplet seems to be a very sensitive tracer of accretion or outflows. Calvet et al. 2004 and Ingleby et al. 2013 analyzed these lines in low resolution spectra and found a relationship between the CII] luminosity and the accretion luminosity. The study of the C II] flux ratios within a small range of wavelengths provides a good opportunity to investigate TTS properties because they are optically thin and their ratios do not depend on the geometry of the accretion system and are only slightly affected by the large uncertainties associated with extinction determination.



Spectrum of TW Hya with the best S/N of the sample. The principal lines studied in this work are indicated.



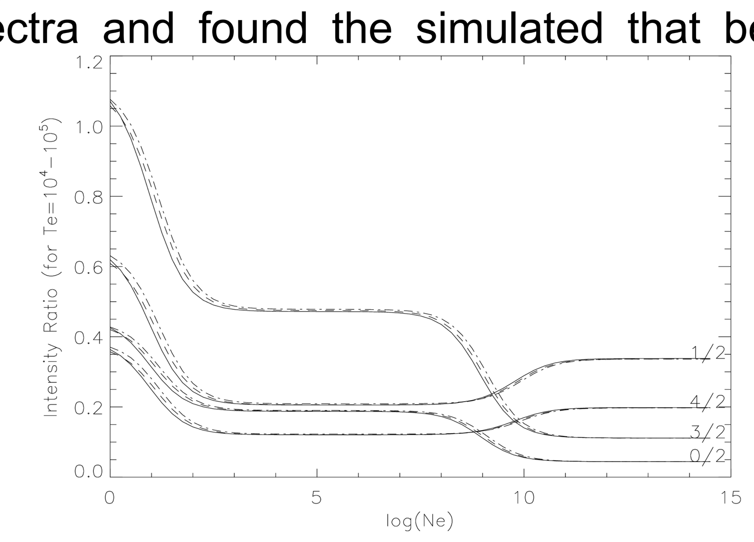
Spectra of some stars in the sample in the range of interest. Dashed lines inidicate the C II] quintuplet.

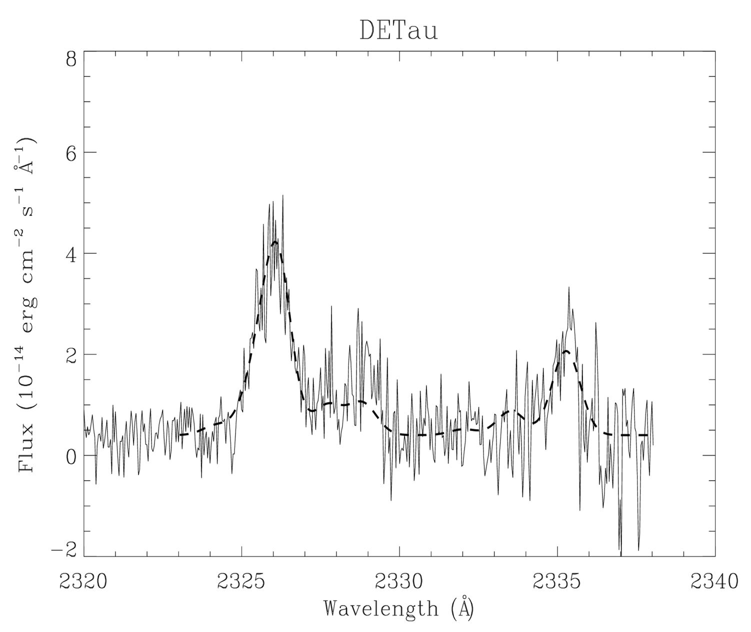
2.- THE METHOD

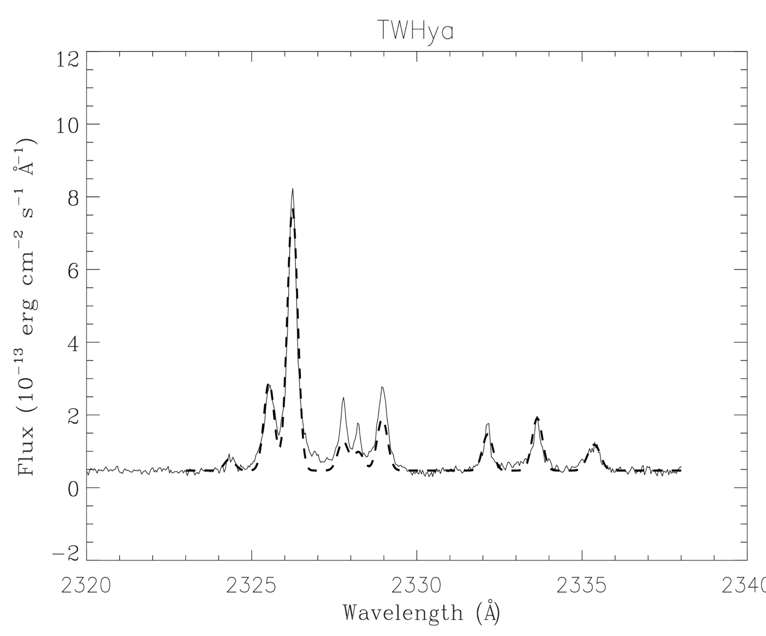
C II], Fe II] and Si II] features are optically thin tracers of the radiating plasma, suitable to be used to measure directly their properties. The combined analysis of C II], Fe II] and Si II] ratios yields enough information to determine unambiguously the physical properties of the region where the lines are formed. Making use of the emissivities from CHIANTI, we have computed the flux ratios relative to the C II] (2326.11 Å) line of the C II], Fe II] and Si II] lines in the range 2323-2338 Å, for a grid of electron temperatures 4.0 ≤ log T_e(K) ≤ 5.5 and densities 0.0 ≤ log n_e(cm^{-3}) ≤ 14.5 with resolutions 0.025 dex in log (T_e) and 0.25 dex in log (n_e). We have assumed that the lines profiles are adequately reproduced by Gaussian functions. In this manner, we have built a grid of simulated spectra in the spectral range of interest. We have developed a code consisting in using the grid of theoretical line ratios to fit multi-Gaussian components to the observed spectra and found the simulated that best fitting with that one by least squares.

__Right figure:__ emissivity ratios of the C II] lines (0,1,2,3,4) relative to the 2326.11 Å (2), as a function of electron density.

__Bottom figures:__ two examples of the observed spectrum (solid line) with their best fit (dashed line).





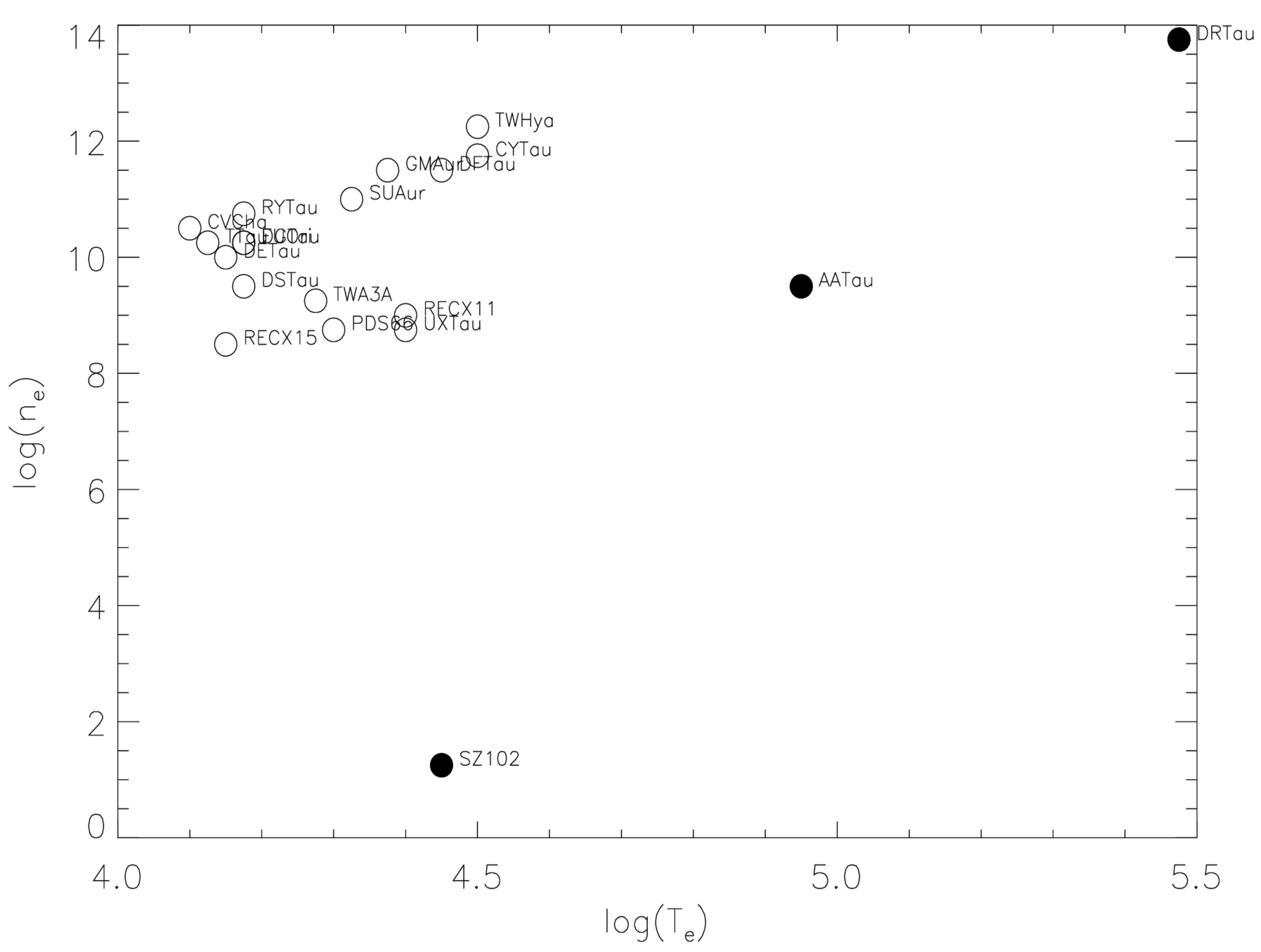


3.- RESULTS

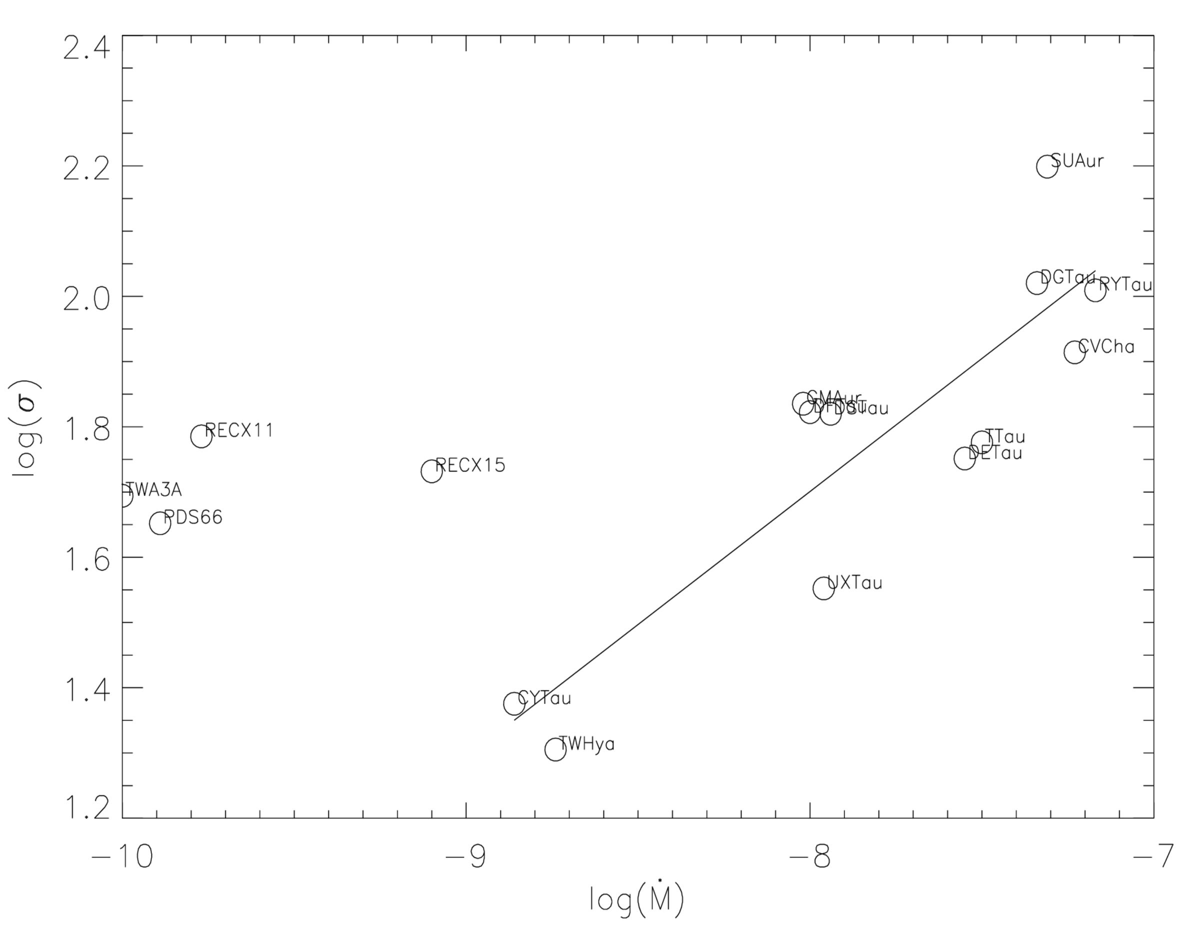
From the fit we obtained T_e, n_e, broadening line, line shifted and flux for each line and spectrum. In most TTSs, **the C II], Si II] and Fe II] radiation seems to be produced in an extended magnetospheric structure characterized by 10^{8} ≤ n_e ≤ 10^{12} cm^{-3} and $10^{4.1}$ ≤ T_e ≤ $10^{4.5}$ K**. The line broadening is suprathermal except for two stars (TW Hya and CY Tau). The dispersion depends on the electron temperature of the radiating plasma and on the accretion rate, suggesting a **connection between the line formation region and the accretion process.** This is consistent with the **line radiation being dominated by the magnetospheric accretion flow, close to the disk.** For TW Hya and CY Tau, the densities and temperatures are higher than for the rest of the stars and similar to the observed in atmospheres of cool stars. Also, the line broadening is thermal. Therefore, the observed emission lines **in TW Hya and CY Tau are formed in a different region in the magnetospheric accretion flow (likely close to the star).** In good agreement with this picture, the density and temperature in the line formation region are below the theoretical predictions for the density and temperature in the accretion shock (n_e ≈ 10^{13} cm^{-3} and T_e ≈ 10^{6} K) and about the densities and temperatures expected in the funnel flow (n_e ≈ 10^{9}-10^{12} cm^{-3} and T_e ≈ 5x10^{3}-$10^{4.5}$ K) (see for example Calvet et al. 1998 or Muzerolle et al. 2001).

The C II] quintuplet can be used as a reliable tracer of the mass accretion rate on the star. C II] luminosity increases as the accretion rate does it in agreement with previous results by Calvet et al. 2004 and Inbleby et al. 2013.

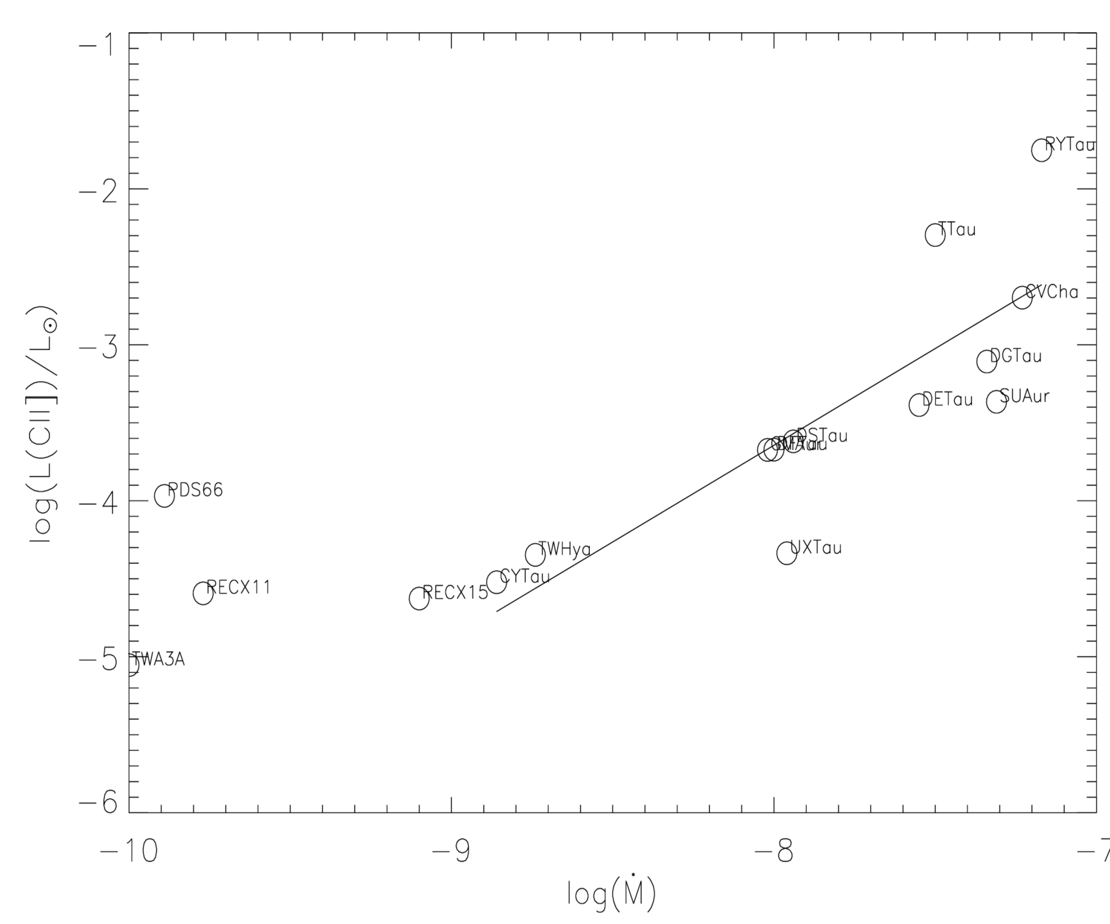
Evidence of the line emission region sharing **similar properties in the base of the outflow and the accretion flow** have been found for: DG Tau, RY Tau and FU Ori. The derived properties (T_e, n_e) agree with previous calculations by Gómez & Verdugo 2001, 2003.



Results of ne and Te from the fitting procedure. Filled circles are the stars with values out of the range where most stars are.



Correlation between dispersion and accretion rate.



Correlation between the C II] luminosity and the accretion rate.