Determining the Absorption towards Classical T Tauri Stars from Hydrogen Emission Lines

The Harvard community has made this article openly available. Please share how this access benefits you. Your story matters

Citation

Published Version
http://www.mpia-hd.mpg.de/homes/ppvi/posters/2S010.html

Citable link
http://nrs.harvard.edu/urn-3:HUL.InstRepos:12414732

Terms of Use
This article was downloaded from Harvard University’s DASH repository, and is made available under the terms and conditions applicable to Open Access Policy Articles, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#OAP
Abstract: Classical T Tauri stars (CTTS) are low-mass pre-main sequence objects surrounded by an accretion disk and still partially embedded in the parent circumstellar cloud. We observed a sample of 20 CTTS covering different ages and evolutionary stages with VLT/X-Shooter. Its wide wavelength coverage allows us to simultaneously observe H\textalpha\ lines in the Balmer, Paschen, and Brackett series, which supposedly originate mainly from the accretion funnel. We present the results of our study of reddening in CTTS using ratios of common upper level lines. We determine new extinction values $A_V$ for several objects, but cannot find deviations from the standard parametrisation $A = A_V \cdot \lambda^{-1.8}$ (Martin & Whittet 1990) of the reddening at infrared wavelengths.

1. Determining $A_V$ from Common Upper Level Hydrogen Lines

The photon rate $F_{\text{em}}$ produced by a specific transition in an optically thin hydrogen gas is determined by

$$F_{\text{em}} = N_u \cdot A_{ul},$$

where $N_u$ is the population density of the upper level and $A_{ul}$ the Einstein coefficient of spontaneous emission. Stimulated emission is not relevant here. In ratios of lines from a common upper level the population density cancels and the ratio is given by the Einstein coefficients only:

$$\frac{F_{\text{em}1}}{F_{\text{em}2}} = \frac{A_{ul1}}{A_{ul2}}.$$

Thus, the ratio is independent of the temperature and density of the emitting gas. Any deviation from this ratio has to be caused by reddening. At infrared wavelengths the reddening is parametrised by a wavelength dependent power law $A = A_V \cdot \lambda^{-\alpha}$ with the extinction value $A_V$ and the exponent $\alpha$, e.g. $\alpha = 1.84$ between 0.9 $\mu$m and 5 $\mu$m (Martin & Whittet, 1990, ApJ, 357, 113). From the difference between the expected and the observed ratios we can gather information on the reddening.

2. Example Spectrum

The plots show the flux calibrated VLT/X-Shooter spectrum of RU Lup annotated with important emission lines (H\alpha is cut off). In the lower plot the profiles of the hydrogen lines Pa\beta, Pa\gamma, Br\alpha, and Br\alpha10 are shown in insets. The spectrum was corrected for telluric absorption using simulated atmospheric transmission spectra computed by the code LBLRTM (Line-By-Line Radiative Transfer Model, Clough et al. 2005, JQSRT, 91, 233). The omitted parts of the spectrum are too heavily contaminated by telluric lines to obtain a reliable correction.

3. Measuring Line Fluxes

For the 6 objects in our sample that show more than one common upper level pair of the Paschen and Brackett lines in emission we measured the line fluxes by subtracting a template spectrum, i.e. the spectrum of a matching non-accreting star from the sample. In this way we take into account that the emission first has to fill up the photospheric absorption region. The best template is chosen by looking at a number of emission-free regions. To calculate the ratios we only use the blue side of the line as the red side is often affected by absorption from the accretion funnels. The plots below show as example the lines Br\alpha11 (left) and Br\alpha12 (right) of RU Lup (black) together with the template IM Lup (red).

4. Results of Fitting Reddening Law $A = A_V \cdot \lambda^{-\alpha}$ in Our Sample

We then determine the difference $E(\lambda_{\text{obs}})/E(\lambda_{\text{std}})$ between observed and expected ratios, i.e. the extinction, which is shown for each object in black in the plots below, and fit the power law $A = A_V \cdot \lambda^{-\alpha}$ to it.

5. Conclusions & Outlook

- Using common upper level lines allows to determine $A_V$ without detailed knowledge about the object and independent of temperature and density of the emitting gas.
- Test of phenomenological law of reddening at infrared wavelengths needs lower errors, e.g. by using model spectra plus a black body as templates in the flux measurements.
- Compare to results from other studies of extinction and dust properties, e.g. Spitzer data:
  - $A_V$ values from different wavelength regions
  - Look for connections, e.g. with the silicate features at 10 & 18 $\mu$m
  - Can NIR data add new information on dust properties?
- What consequences follow for the environment of CTTS?