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Physical parameters of T Tauri stars

Excitation and ionization equilibrium in the formation of spectral lines

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Abstract. The study of T Tauri (TT) stars is very important to investigate star formation and stellar evolution. We studied optical spectra aiming to estimate stellar parameters such as effective temperature (T_{eff}), metallicity ([Fe/H]), radial velocity (v_{rad}) and rotational velocity ($v \sin i$) for a sample of TT stars, in particular those associated with the Sh2-296 nebula. This work describes the methodology for stellar parameter determination by using spectral line measurements. Initially, we used medium-resolution spectra obtained with Gemini Multi-Object Spectrometer (GMOS), which provided the identification of the main characteristics of the TT stars. Spectra of higher resolution acquired with the Fiber-fed Extended Range Optical Spectrographs (FEROS) were investigated, allowing us to estimate stellar parameters of the stars PDS 74 and PDS 83 and classify them as Classical TT (CTT). The results were compared with literature showing good agreement. Determining these parameters for other stars as well as estimating their surface gravity ($\log g$) will be the next steps of this ongoing project

Resumo. O estudo de estrelas T Tauri é muito importante na análise da formação e evolução estelar. Estudamos espectros ópticos visando estimar parâmetros estelares como temperatura efetiva, metalicidade, velocidade radial e velocidade de rotação para uma amostra de estrelas TT, em particular aquelas associadas com a nebulosa Sh2-296. O presente trabalho descreve a metodologia para a determinação de parâmetros estelares usando medidas de linhas espectrais. Inicialmente, usamos espectros de média resolução obtidos com o GMOS, que tornaram possível a identificação das principais características da estrelas TT. Espectros de maior resolução, obtidos com o FEROS, foram analisados possibilitando estimar os parâmetros estelares das estrelas PDS 74 e da PDS 83 e classificá-las como TT Clássicas. Os resultados foram comparados com a literatura mostrando boa compatibilidade. Determinar estes mesmos parâmetros para outras estrelas bem como estimar gravidade superficial serão os próximos passos deste projeto.

Keywords. Stars: formation – Stars: fundamental parameters – Stars: pre-main sequence – Stars: variables: T Tauri, Herbig Ae/Be

1. Introduction

T Tauri stars are young low-mass stars (0.5 - 2 $M_{\odot}$) with typical features showing strong absorption lithium line (λ6708 Å) as an indicator of their youth and the Hα emission line, that point out to accretion process and is used to classify the TT stars between two classes: Classical T Tauri (CTT), that have a disk, and the Weak-lined T Tauri (WTT), that show similar circumstellar characteristics, but without accretion activity (e.g. Fernandes et al. 2015).

In the broader context, the goal is to determine parameters that hold information about the physical environment of pre-main sequence stars, such as T_{eff}, [Fe/H], v_{rad}, and $v \sin i$ to better understand the star formation. To do that, optical spectra of TT stars of the nebula Sh2-296, which is a special kind of star formation scenario that could be associated with three supernova events (Fernandes et al. 2019), as well as the spectra of others TT stars, were analyzed based on concepts of quantum physics and statistical mechanics related to the formation and intensity of spectral lines.

In the Secs. 2 and 3 we describe the methodology adopted to analyze the spectra of stars associated with the Sh2-296 nebula and the stars PDS 83 and PDS 74, respectively. Conclusions are summarized in Sec. 4.

2. Stars associated with Sh2-296

Our first sample contains six TT associated with the nebula Sh2-296. These stars were studied using GMOS spectra with resolution $R = 1900$, which was sufficient to find some of the typical features of this kind of star, as shown in Fig. 1. To confirm the identification of Li line, we also searched for the Ca I line at 6717.7 Å (Fig. 1 – bottom panel) since it is expected to be ~9.9 Å apart from the Li line. In three of them, the offset between the Li I and Ca I (λ6718 Å) lines was not the expected value (9,9 ± 0,5) Å which can be due to the blend with other non-resolved lines that could be affecting the measurements. Due to the non-reliable identification of Fe lines for the TTs in Sh2-296, the stellar parameters were not estimated for this sample.

3. PDS sample

In order to apply the methodology to determine the physical parameters, we needed to use FEROS spectra, with $R \approx 48\,000$, which are available for another sample of TT stars. In this case, PDS 74 and PDS 83 were studied. For these stars, the typical features were identified by the same method used for the Sh2-296 sample (Fig. 2).

The greater resolution of FEROS spectra has allowed the determination of v_{rad}, comparing central wavelengths with Moore, Minnaert & Houtgast (1966), and $v \sin i$, using the empirical model proposed by Strassmeier et al. (1990). It was also possible to estimate T_{eff}, applying the line ratios method. Finally, the metallicity was evaluated using the temperature, the equivalent width of Fe I line in 6705 Å, and isoabundaces curves from Padgett (1996). The estimated parameters are shown in Tab. 1. Measurements at 10% width of Hα emission (W_{H_α}) were taken to classify them, according to the method proposed by White & Basri (2003), in which widths greater than 270 km s^{-1} indicate

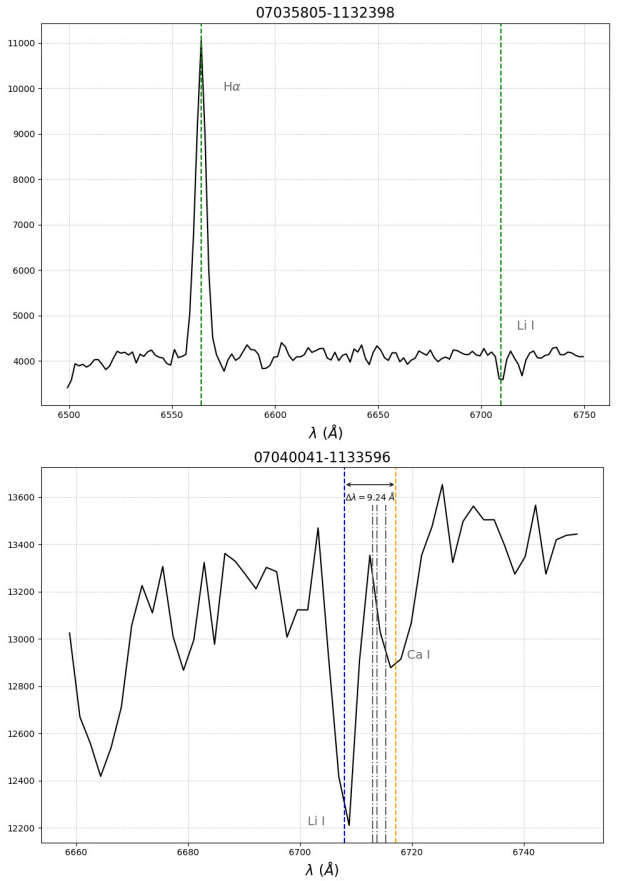

Figure 1. Example of a section in one of the GMOS spectra studied with identification from the 2MASS catalog. Intensity is shown in arbitrary units. Top panel: green dashed lines highlight the position of the Hα and Li λ6708 Å lines; bottom panel: observed lines (with no correction for Doppler effect) of lithium (blue dashed line) and calcium (orange dashed line). The position of 3 weak Fe lines (measured in the rest reference), which could affect the measurements of Li and Ca lines, are indicated by gray dashed lines.

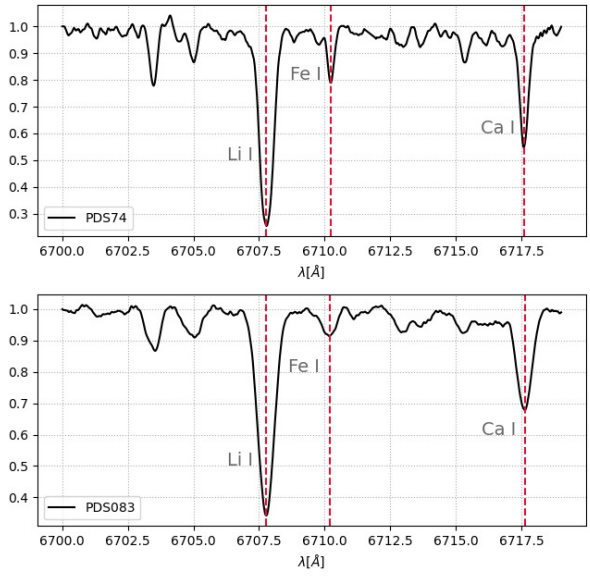

Figure 2. Cut in the FEROS spectra of PDS 74 and PDS 3, showing the lines Li I (λ6708 Å), Fe I (λ6710 Å), and Ca I (λ6718 Å).

Table 1. Stellar parameters estimated for PDS 74 and PDS 83.

Star	v_{rad} (km s^{-1})	$v \sin i$ (km s^{-1})	T_{eff} (K)	[Fe/H] (dex)	W_{H_α} (km s^{-1})
PDS74	−4.1±0.2	9.8±0.5	4440±120	−0.2±0.2	547±5
PDS83	−2.5±0.4	19±1	4760±130	0.2±0.2	554±5

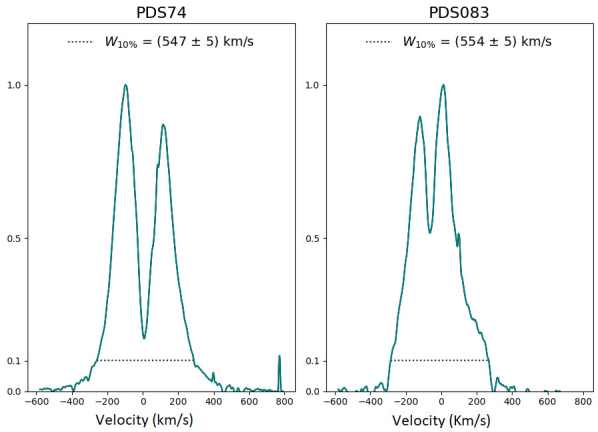

Figure 3. Hα line profile with the measurement of 10% width emission for PDS 74 and PDS 83.

that the star is a CTT. Considering this, both of the PDS stars were classified as CTT (Fig. 3). Comparison with literature data (e.g. Frasca et al. 2017; Rojas, Gregorio-Hetem & Hetem 2008) validated most of our results.

4. Conclusion

The spectroscopic analysis, based on statistical mechanics and quantum physics, proved to be determinant to understand the physical environment in which stars are found. Moreover, applying this kind of study to TT stars makes it possible to understand more about star formation.

GMOS spectra with $R \approx 1900$ were very useful to identify the main optical features of TT stars, contributing to the study of Sh2-296 nebula, and to learn the methods associated with this identification. On the other hand, using FEROS spectra with higher resolution, we could estimate the physical parameters initially intended for the TT stars PDS 74 and PDS 83, as well as, classify them as CTT.

As prospects of this project, we want to find the same physical parameters for other TT stars. In addition, we have the goal of estimating other parameters, such as surface gravity.

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References

Fernandes, B.; Gregorio-Hetem; J., Montmerle, T.; Rojas, G., 2015, MNRAS 448, 119
Fernandes, B.; Montmerle, T.; Santos-Silva, T.; Gregorio-Hetem; J., 2019, A&A, 628, 44
Frasca A., Biazzo K., Alcalá J. M., Manara C. F., Stelzer B., Covino E., Antoniucci S., 2017, A&A, 602, A33
Moore, C. E., Minnaert, M. G. J., & Houtgast, J. 1966, The solar spectrum 2935 Å to 8770 Å
Padgett D. L., 1996, ApJ, 471, 847
Rojas G., Gregorio-Hetem J., Hetem A., 2008, MNRAS, 387, 1335
Strassmeier K. G., Fekel F. C., Bopp B. W., Dempsey R. C., Henry G. W., 1990, ApJS, 72, 191
White, R. J., Basri, G., 2003, ApJ, 582, 1109