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# Study of the physical and chemical properties of the PDS 70 star

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**Abstract.** The work in progress aims to determine some physical and chemical characteristics of the young star PDS 70 through spectroscopic analyses. To improve the accuracy of the measurements, the spectra of the star PDS 70 were processed to increase the signal-to-noise ratio. The adopted metodology aims to estimate the stellar atmospheric parameters and spectral syntheses will be performed for some elements of interest in the determination of stellar parameters and abundances.

**Resumo.** O trabalho em desenvolvimento busca determinar algumas características físicas e químicas da estrela jovem PDS 70 por meio de análises especroscópicas. Para melhorar a precisão das medidas, foi realizado um tratamento com os espectros de PDS 70 visando aumentar a razão sinal-ruído. A metodologia adotada visa estimar parâmetros atmosféricos da estrela e realizar síntese espectral para alguns elementos de interesse na determinação de parâmetros estelares e abundâncias.

**Keywords.** Techniques: spectroscopic – Stars: pre-main sequence – Protoplanetary disks

## 1. Introduction

The planetary system associated with PDS 70 is one of the most studied systems today. Discovered at the Pico dos Dias Observatory (Gregorio-Hetem et al. 1992) PDS 70 is a T Tauri star located at a distance of 100 pc (Steinmetz et al. 2020). Direct imaging of its protoplanetary disk (Keppler et al. 2018), carried out with the ALMA (The Atacama Large Millimeter/submillimeter Array), revealed the presence of two exoplanets: PDS 70b and PDS 70c, as well as the possible existence of a moon associated with one of them as shown in Figure 1 (Isella et al. 2019). More recently, using the James Webb Space Telescope, evidence of water vapor was found in the inner disk of the system (Perotti et al. 2023). The presence of water in this region opens up interesting topics of debate, for example:

- Formation of water along with the formation of rocky planets.
- Transport of water from the outer disk to the inner disk with fluxes and distances not previously observed.

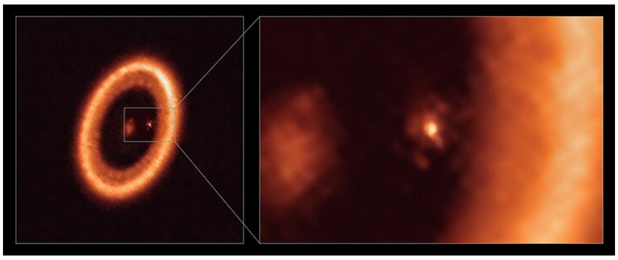

**Figure 1.** Image of the PDS 70 planetary system taken by ALMA. In the magnified image on the right, we can see the planet PDS 70c and the presence of a possible satellite, which may be the first image of an extrasolar satellite in formation that has ever been recorded. Figure adapted from Isella et al. (2019).

## 2. Methodology

High-resolution spectroscopic data obtained from the HARPS ( The High Accuracy Radial Velocity Planet Searcher) instrument were utilized in this study. Spectra were fetched from the ESO public archive for the 3.6-meter NTT telescope.

A data processing was implemented, encompassing the following steps:

- Doppler Correction: Individual spectra were corrected for the Doppler shift due to the star's radial velocity.
- Spectral Combination: Spectra were combined using both mean and median weighting to enhance the signal-to-noise ratio.
- Continuum Normalization: The spectral continuum was normalized to eliminate instrumental and atmospheric effects.

Figure 2 clearly shows the impact of data processing on the signal-to-noise ratio, which is significantly increased.

The effective temperature (Teff) was determined through the line ratio method, as detailed in Maldonado et al. (2015). This technique involves fitting empirical functions to ratios of equivalent widths of spectral lines, establishing a direct correlation between these ratios and stellar temperature, as shown in Figure 3. This approach is particularly advantageous for T Tauri stars, characterized by a limited number of isolated spectral lines.

The following empirical functions were employed:

- Hoerl function: $T_{\rm eff} = ab^r r^c$.
- Modified Hoerl function: $T_{\rm eff} = abr^c$.
- Exponential function: $T_{\rm eff} = ab^r$.
- Power-law function: $T_{\rm eff} = ar^b$.
- Logarithmic function: $T_{\rm eff} = a + b\ln(r)$.

Where $a, b, c$ are fitting parameters and $r$ is the ratio of equivalent widths.

By applying these functions to nine pairs of spectral lines, individual Teff estimates were obtained. The final effective temperature was determined through a weighted average of these estimates, yielding a value of 4173 ± 707 K.

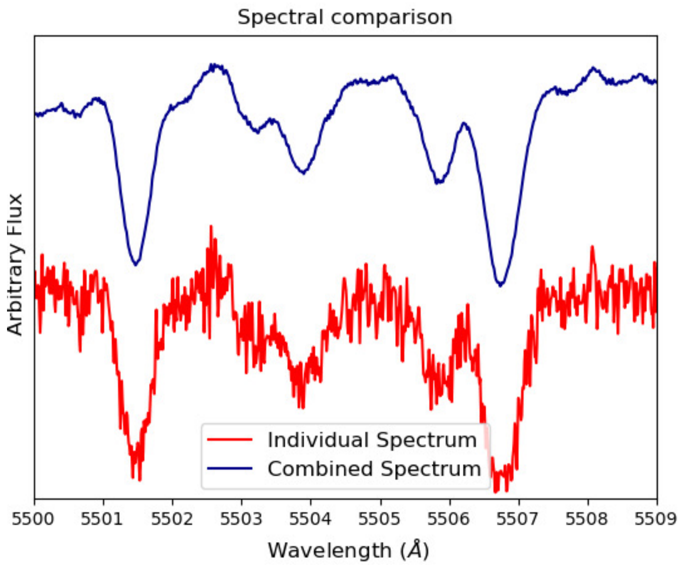


**Figure 2.** In the top, the spectrum represents the combined data, whilea typical individual spectrum is shown in the bottom. Both are from PDS 70 star.

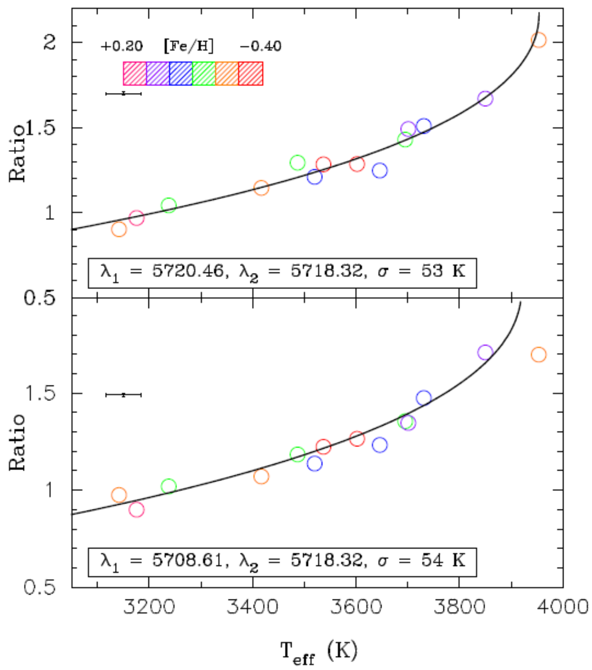


**Figure 3.** Example of the determination of fitting parameters for temperatures. Adapted from Maldonado et al. (2015).

## 3. Partial Conclusions and Future work

The study of the chemical characteristics of PDS 70 offers valuable insights into planetary system formation and planet-star interactions.

Spectral processing significantly reduced noise compared to individual spectra. Normalization was crucial for identifying lines of interest, even in the presence of line blending. The estimated temperature aligns with literature values, though the uncertainty of 707 K provides a reasonable starting point for spectral synthesis.

We are currently analyzing specific spectral lines to determine the projected rotational velocity (v sin(i)) and macroturbulence velocity, which are essential for spectral synthesis and deriving elemental abundances like lithium. Future research will delve deeper into spectral line analysis to obtain precise elemental abundances and explore the dynamical processes shaping the PDS 70 system.

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