Lab 2 — Understanding Accretion, Outflows, and Star Formation in T Tauri

Due Sept 28, 2025

Goal: Measure accretion and outflow properties for a young stellar system.

Background: T Tauri stars are pre-main sequence stars less than ∼10 million years old. They are surrounded by disks, from which they are actively accreting mass, and produce outflows as a result of this accretion. We'll be looking at optical-to-near infrared spectra of the first-discovered star of this class, T Tauri.

T Tauri is found in the constellation Taurus, or between Nā Kao and Hōkūlei (Orion's belt and Auriga), and between the star cluster Makaliʻi and the star ʻAukele (Aldebaran).

1 Lab

1.1 Download the data

We'll start off with an infrared spectrum of T Tauri here. These are data that Mike Connolley took on IRTF a few years back using the iSHELL instrument. Download and plot the data. This spectrum is in W m^{-2} μm^{-1}, the units make me want to die.

1.2 Derive the extinction and accretion component

T Tauri star spectra can be modeled with multiple components: 1) the underlying spectrum of a main-sequence star, 2) dust extinction, and 3) a bluer (black body) continuum caused by mass accreting onto the star. Construct a model with these three components that can be compared to the data. Start by building an initial model with guesses for all three components; then try to fit the model to the data. For the first component, try to figure out (or look up) the spectral type, and find a model IR spectrum for that type.

1.3 Measure the mass accretion rate

Hydrogen emission lines are thought to trace hot, optically thin gas accreting onto the surface of a young star. Identify two Hydrogen emission lines in the spectrum that can trace accretion luminosity (check the literature), and measure the luminosities by integrating over the line profiles. Make sure you've corrected for extinction.

Use relationships from the astronomical literature to convert from line luminosity to mass accretion rate; alternatively, you can approximately convert from line luminosity to accretion luminosity and then approximately to accretion rate via $L_{acc} = GM_*\dot{M}/R_*$ (steady state accretion, see here). How does the accretion luminosity compare to the integrated black body luminosity from your model?

1.4 Measure wind outflow velocity

Lines with "P Cygni" profiles are a good indication that an outflow is happening, because we see distinct red- and blue-shifted components. Find a line with a P Cygni profile, identify it, and use measure the outflow velocity. Compare to velocities derived from the bluest/reddest components of Hydrogen lines.

2 Write-Up

Include the following sections. Submit report as a PDF via email or google classroom; Google docs links will not be accepted. Include a single .py file (*not Jupyter or Colab format*) with your code. LaTeX is encouraged but not required.

2.1 Hua

Introduce the theory and purpose of the lab. How does this project help us understand the formation of stars?

2.2 Haʻalele

Describe the data, including where it came from (IRTF, iSHELL). Include plots of the stellar spectrum.

2.3 Huakaʻi

Discuss your process, including how you fit the spectral components to the T Tauri spectrum and measured the accretion rate and outflow velocity.

2.4 Hoʻina

Compare your measurements to other observations of T Tauri stars in the literature, and to the results from your classmates. Why is the hydrogen velocity different from the P Cygni line profile you measured? Is T Tauri's mass accretion typical of these types of stars, and how does it compare to older/younger stars? How does mass accretion rate change over the formation timescale of a star? Why do different lines trace different physical processes?

2.5 Hāʻina

What uncertainties were there? What would you need to gain a better understanding of accretion/outflows in T Tauri stars, or the process of star formation in these stars as a whole? What other diagnostics or measurements could help you understand stellar formation and accretion?