RADIAL VELOCITY CONFIRMATION OF EXOPLANETS AROUND K DWARF STARS

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Abstract

This project aims to confirm exoplanet candidates around K dwarf stars selected from the TESS (Transiting Exoplanet Survey Satellite) candidates list using radial velocity (RV) data from the CHIRON spectrograph at the SMARTS 1.5-meter telescope. K dwarf stars are stable, long-lived stars that create favorable environments for habitable planets. The CHIRON data and Python scripts were created for Paredes, L. A., et al. (2021). The data was cross-matched with our catalog of 615 nearby K dwarf stars, identifying four viable targets with sufficient observational coverage. The Python scripts were used to prepare the spectroscopic data by removing the blaze function and correcting for Earth's Doppler shift, then calculating precise RV values and uncertainties. The final results of these scripts allow us to determine whether each investigated star hosts a confirmed planetary companion. Due to insufficient data, no planets were able to be confirmed by this project. A follow-up will be conducted, focusing on HIP074981.

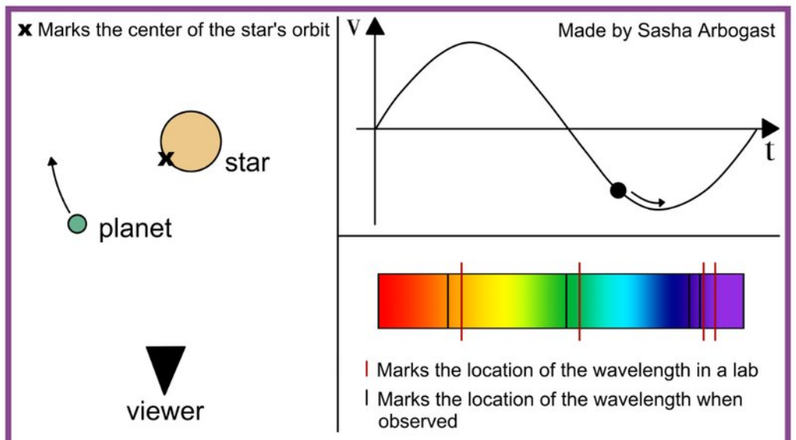
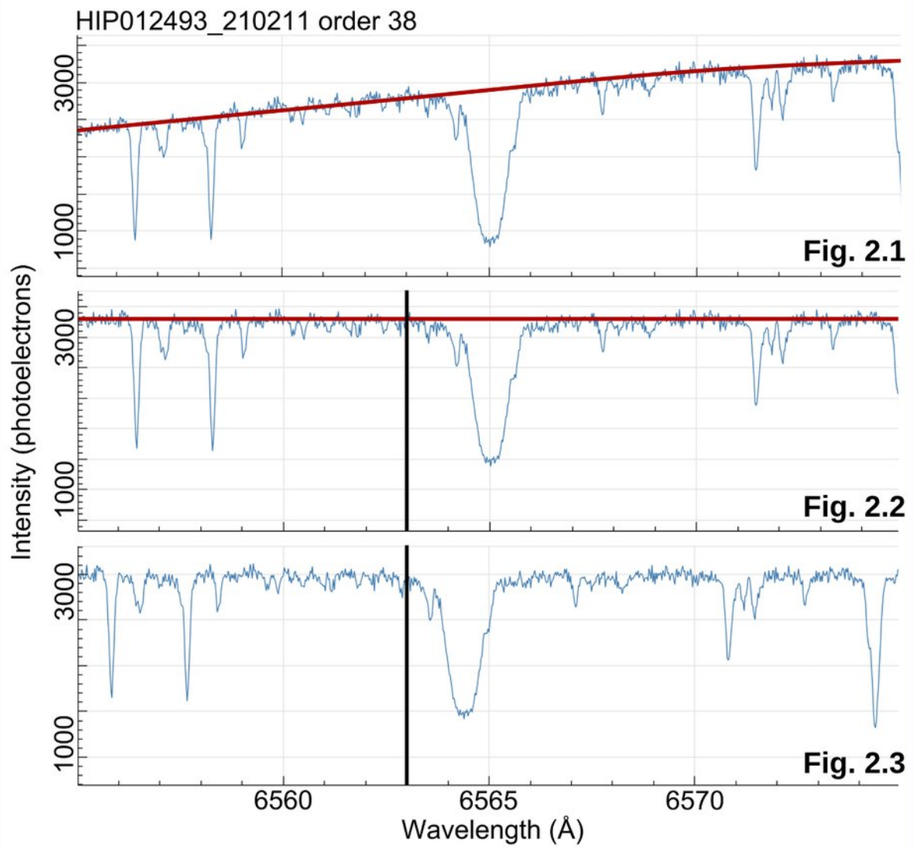


Figure 1: Schematic Explaining Radial Velocity

How Did We Choose Our Stars?

Out of a list of 615 K dwarf stars, we needed to determine which stars to focus on. We cross-matched the K dwarfs with 7,463 TESS candidates from the NASA Exoplanet Archive (as of July 2025), using TOPCAT for the data matching process, with the added parameter of only outputting stars that the program confirmed were the same object.* The resulting list contained 16 stars, and only 4 of those had multiple CHIRON observations available, spanning 12-18 months per star. Our stars chosen for confirmation were HIP012493, HIP074981, HIP115752, and HIP114941.

*Objects with less than 10 arcseconds of separation between two R.A. and Declination measurements



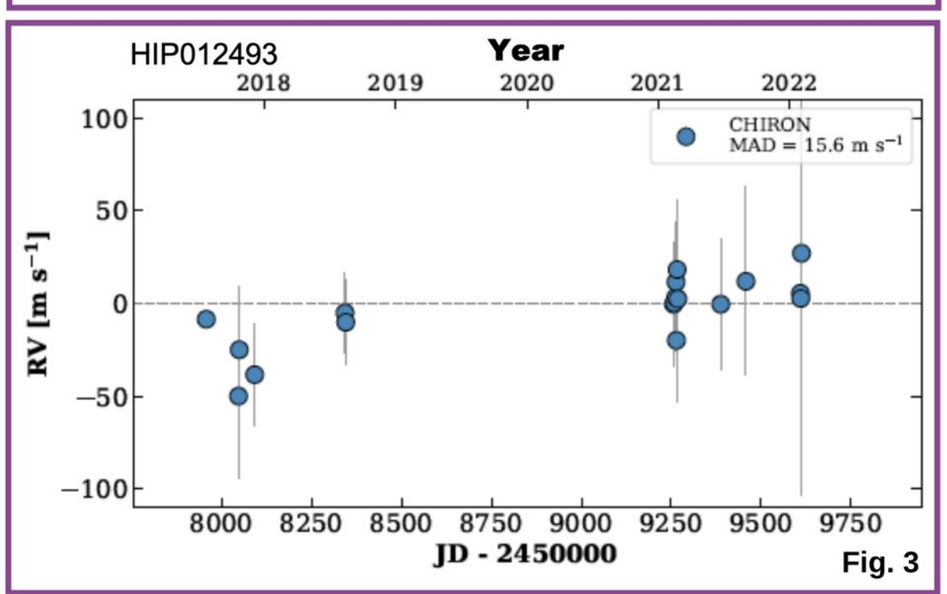


Fig. 3

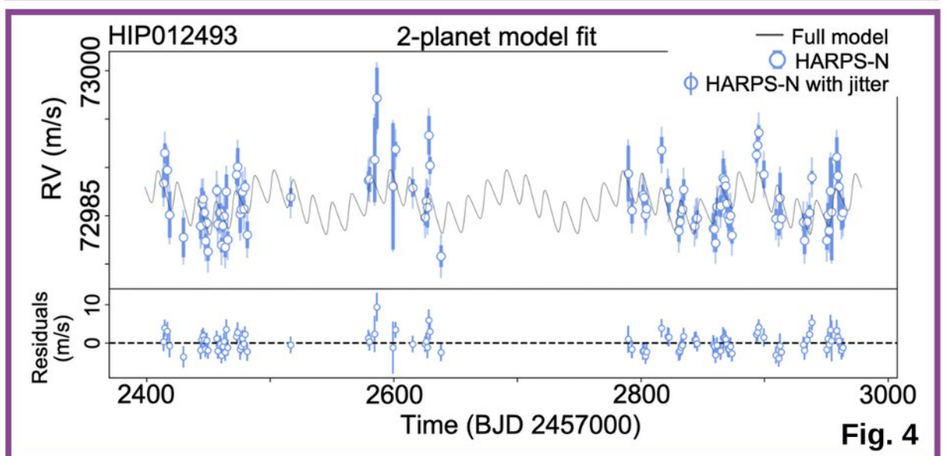


Fig. 4

Our Three Step Process

Blaze Function: When looking at raw spectroscopic data, there is a curve across the wavelengths known as the blaze function, see ***Fig. 2.1*** on the left. This script removes the curve so we can easily see where each absorption line is located in wavelength space. An example of the flattened spectrum is shown in ***Fig. 2.2*** on the left.

Barycentric Correction: When observing on Earth, we ourselves have a velocity. ***Fig. 2.2*** shows an uncorrected spectrum. This script removes the movement of the Earth from the equation using the barycentric correction algorithm from Wright & Eastman (2014). ***Fig. 2.3*** shows a corrected spectrum.

Radial Velocity: So how much is the star actually moving? This script gives us the velocity of the star using the red/blue shift of the spectrum. ***Fig. 2.3*** is what we put into our RV code. The result is the radial velocity phase diagram in ***Fig. 3***.

Results

HIP012493: Our RV measurements do not show a clear sinusoidal phase-folded pattern due to insufficient data coverage (9 observations over 43 months). ***Fig. 3*** to the left shows the RV variations with no clear pattern. However, Naponiello, L. et al (2025) confirmed a *sub-Neptune* sized planet orbiting this K star, see ***Fig. 4***. This companion that has an orbital period of 15.67 days, and a mass of 4.8 Earth masses, was discovered using HARPS data. ***Fig. 4*** is a 2 planet model as Naponiello, L. et al (2025) also highlighted the discovery of a new RV candidate.

HIP074981: Our RV measurements do not show a clear sinusoidal phase-folded pattern due to insufficient data coverage (8 observations over 29 months). Although, Dai, F. et al (2023) confirmed a planetary companion with an orbital period of 7.43 days and mass of 9.2 Earth masses using Keck/HIRES data.

HIP115752: Our RV measurements do not show a clear sinusoidal phase-folded pattern due to insufficient data coverage (3 observations over 5 months).

HIP114941: Our RV measurements do not show a clear sinusoidal phase-folded pattern due to insufficient data coverage (7 observations over 36 months). We are unable to confirm a planetary companion around this star. However, we are planning follow-up observations of this star using CHIRON.

Takeaway: Two stars have confirmed exoplanets, one has insufficient data, and HIP074981 will continue to be explored via follow up CHIRON observations.

Future Work

In our follow-up project, we will use the SMARTS 1.5-meter telescope's CHIRON spectrograph to collect additional data over at varying cadences (primarily focusing on shorter time spans). We will then repeat the process outlined in our methods section above to determine whether or not the planetary candidate around HIP074981 can be confirmed.

References

Contact Me

Acknowledgements

[1] Leonardo Paredes at University of Arizona
[2] The team behind Paredes, L. A., et al. (2021).
[3] The Frances Marx Shillinglaw Women in Science Endowed Fund
[4] NASA 23-MUREP WCU-0017, No. 80NSSC23M0123: Alumnae Network & Career Resources Program -- STEM support anchored at ASC
[5] Goizueta Foundation STEM Success Initiative
[6] The Maria Wornom Rippe '64 STEM Research Endowed Fund