Precision RVs and Helium Spectroscopy of Young Planet Hosts with the Habitable-zone Planet Finder

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Background and Motivation

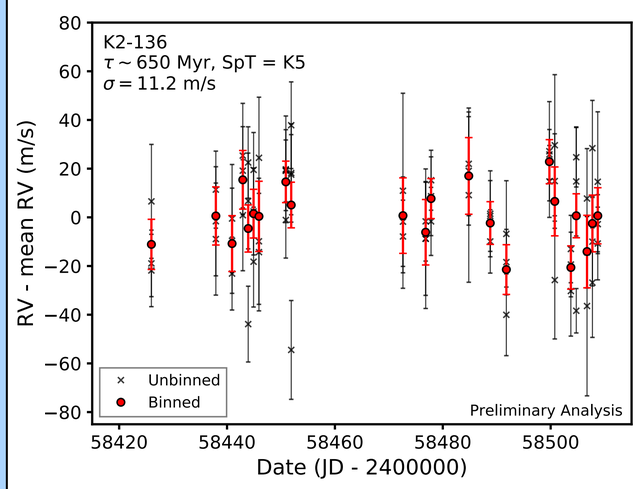
- Distributions of exoplanet properties as a function of age, particularly across their first billion years, can inform models of formation and evolution. These include **orbital parameters (migration mechanisms) and densities (atmospheric loss).**
- K2 has found **over a dozen transiting planets in young clusters and associations.**
- **RVs and transit spectroscopy of young planets are difficult** due to high levels of temporally coherent stellar jitter. This issue is mitigated in the **IR**, which also contains the **He 10830 Å line**, providing a **window into exoplanet atmospheres.**
- We are using the **Habitable-zone Planet Finder,** a new precision NIR spectrograph, to **observe young planet hosts to test models of planetary orbital and atmospheric evolution**.

Conclusions and Takeaways

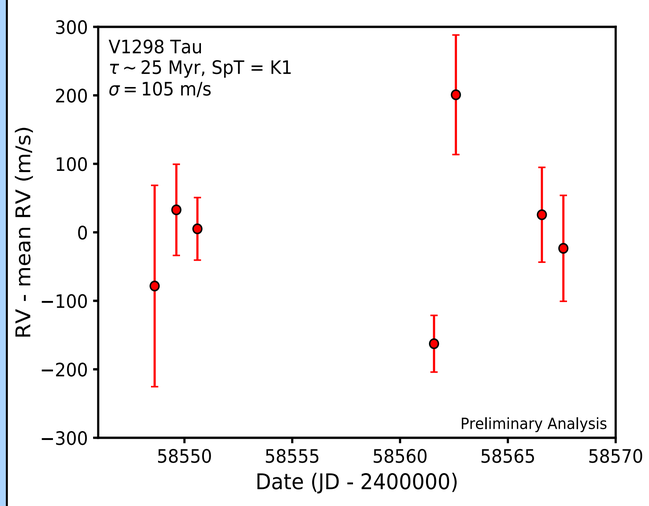
- We are using HPF to observe young transiting planet hosts to **search for non-transiting planets** and perform intensive campaigns to **measure masses and He exospheres** of known transiting planets.
- **Preliminary RV precision is nearing the expected jitter level** for K2-136 (10 m/s at 650 Myr) and V1298 Tau (100 m/s at 25 Myr). We are exploring how intensive campaigns could enable **characterization and subtraction of stellar jitter**.
- Our **He time-series observations demonstrate the limit set by stellar activity** (across age and SpT) in observing exospheres, and we currently achieve **~3–6%.**
- **Our RV survey will be expanded** to longer time baselines for K2 planets and to northern young planets found by TESS.

Precision Radial Velocities of Young Stars with HPF

- Our HPF program of young systems with transiting planets found by K2 consists of both **long term monitoring** to search for additional planets and **intensive campaigns** to determine masses.
- We use broadening functions with theoretical model spectra to derive RVs. Our preliminary analysis achieves an **RV precision of ~10 m/s** for K2-136, already nearing the expected jitter floor in the Hyades (roughly 8 m/s, *Paulson+ 02,04*).



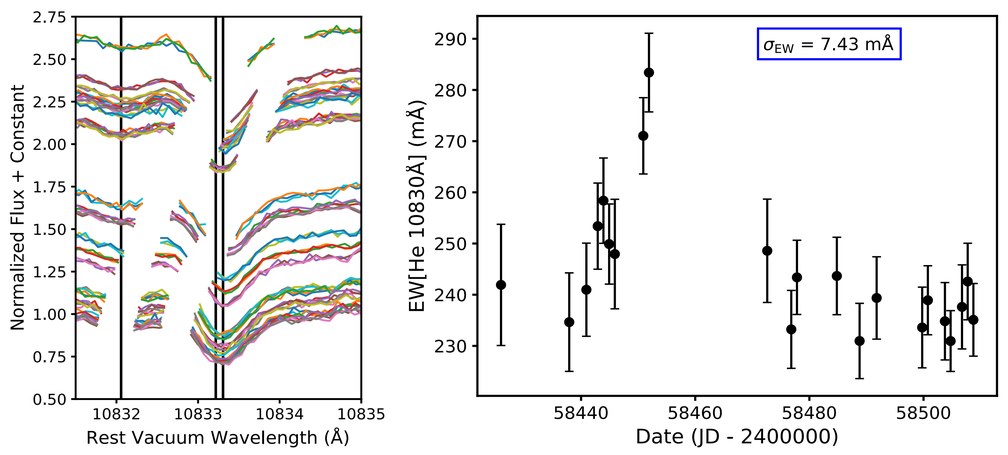
Preliminary RV time series of Hyades member K2-136 (~650 Myr, SpT=K5, *Mann+ 18*), with an RV precision of ~10 m/s. K2-136 demonstrates the precision achievable by our survey, as its known transiting planets' RV signals are expected to be much smaller than the stellar jitter. A 10 m/s semi-amplitude corresponds to planet masses of 25, 40, 90 $M_{\oplus}$ for periods of 1 week, 1 month, and 1 year.



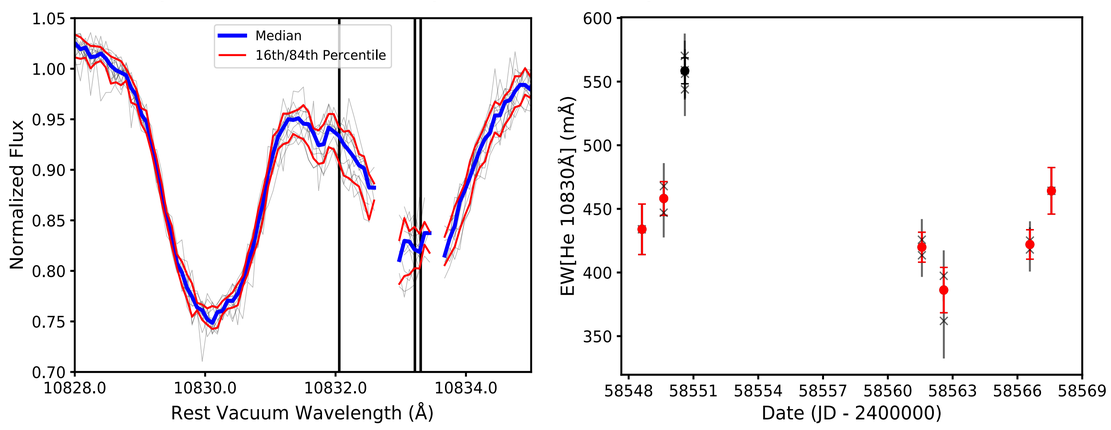
Preliminary RV time series of V1298 Tau (~25 Myr, SpT=K1, *David+ 19*). V1298 Tau is much younger than K2-136, and has larger jitter. We do not detect the transiting planet's signal, but our precision is nearing the expected jitter amplitude (~75 m/s). An intensive campaign, with one or more epochs per night over 1-2 orbital periods, is required to resolve out the stellar variability on the known rotation period and extract the planet's signal.

Helium Spectroscopy of Young Stars with HPF

- **Our ability to detect exospheres around young planets will be limited by the stellar chromospheric spectral line variability**, which we can characterize with our time series observations of young transiting planet hosts.

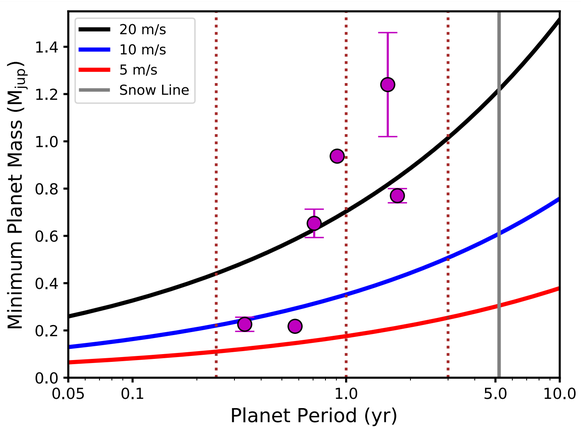


Helium spectra and equivalent widths of K2-136 from 3 months of observations. The line profile is stable over the course of the campaign, with night-to-night variations of ~2.5% for these preliminary EWs. Telluric features are masked in the left panel, where spectra are shown sorted by time and the He triplet is marked by black vertical lines.

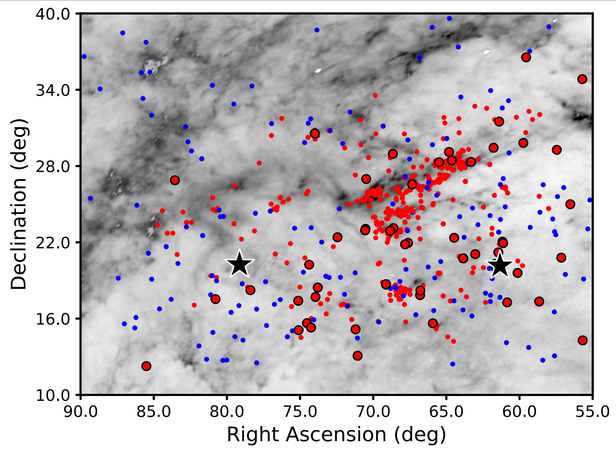


Helium spectra and EWs for V1298 Tau, which we expect to have larger intrinsic spectral variability due to its youth (~25 Myr). The spread in EWs (excluding one outlier) is 6%, although this issue can be mitigated by combining our knowledge of the star's rotational period with an intensive campaign around the transit observation.

Future Work and Directions



Detection limits for our ongoing long-term survey of young planet hosts. Known planets exterior to compact systems of Earth-Neptune-sized planets are plotted (*Cabrera+ 14*, *Neveu-VanMalle+ 16, Mills+ 18*). Given our precision, young analogs to these systems will be discovered by our survey.



Known members of the Taurus star forming region (small red points) with two planet hosts (K2-284 and V1298 Tau) plotted as black stars. Large red circles are new members we have found using *Gaia* and spectroscopy. We will expand this survey to search for coeval neighbors to young planet hosts, in and out of the Taurus region.

- **Improving RVs**: We will use our observations to create empirical templates rather than derive RVs with theoretical models.
- **Continue observations**: We have been allocated time for long-term monitoring of all northern K2 planet hosts and coming TESS discoveries, and an intensive campaign for V1298 Tau.
- **He variability study**: We will use all of our observations to determine typical He variability across age and spectral type, while improving telluric correction to best calculate EWs.
- **Stellar properties**: We will search for coeval neighbors to planet hosts to more precisely derive stellar properties.