Constraining the Evolution and Migration of Young Giant Planets

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We are carrying out a survey targeting intermediate age (~20-200 Myr) Sun-like (GK) stars with the near-infrared Habitable zone Planet Finder spectrograph on the 10-meter Hobby-Eberly Telescope to determine when and how giant planets migrate to small separations.

This four-year program began in 2018. The first (uncorrected) measurements of stellar jitter in the *J*-band for 29 intermediate age stars has a median value of 36.1 m s^{-1} (Fig. 1).

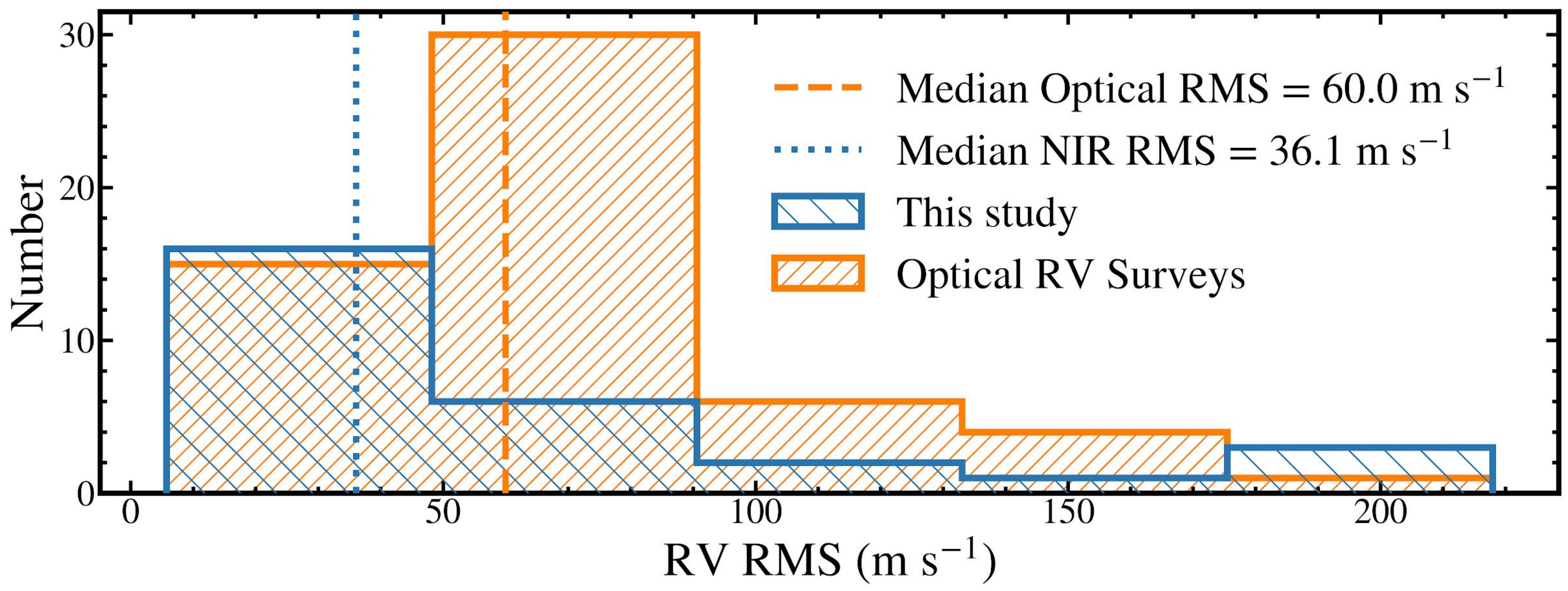


Fig. 1: Optical and NIR RV RMS distributions from literature (orange) and this study (blue) over the same age, spectral type, and rotational velocity range. The median NIR RV RMS (blue dotted line), 36.1 m s^{-1}, is reduced by a factor of ~2 from the median optical RV RMS (orange dashed line) of 60.0 m s^{-1}.

HOW GIANT PLANETS MIGRATE

> It is not clear how giant planets interior to the ice-line arrived at their current location.

> Two processes best explain this population: inspiraling disk migration or three-body dynamical interactions with an outer planet or stellar companion.

> These processes can be distinguished by measuring the frequency of gas giants over time because they operate on different timescales.

> **Mapping when giant planets migrate is the key to determining how they migrate.**

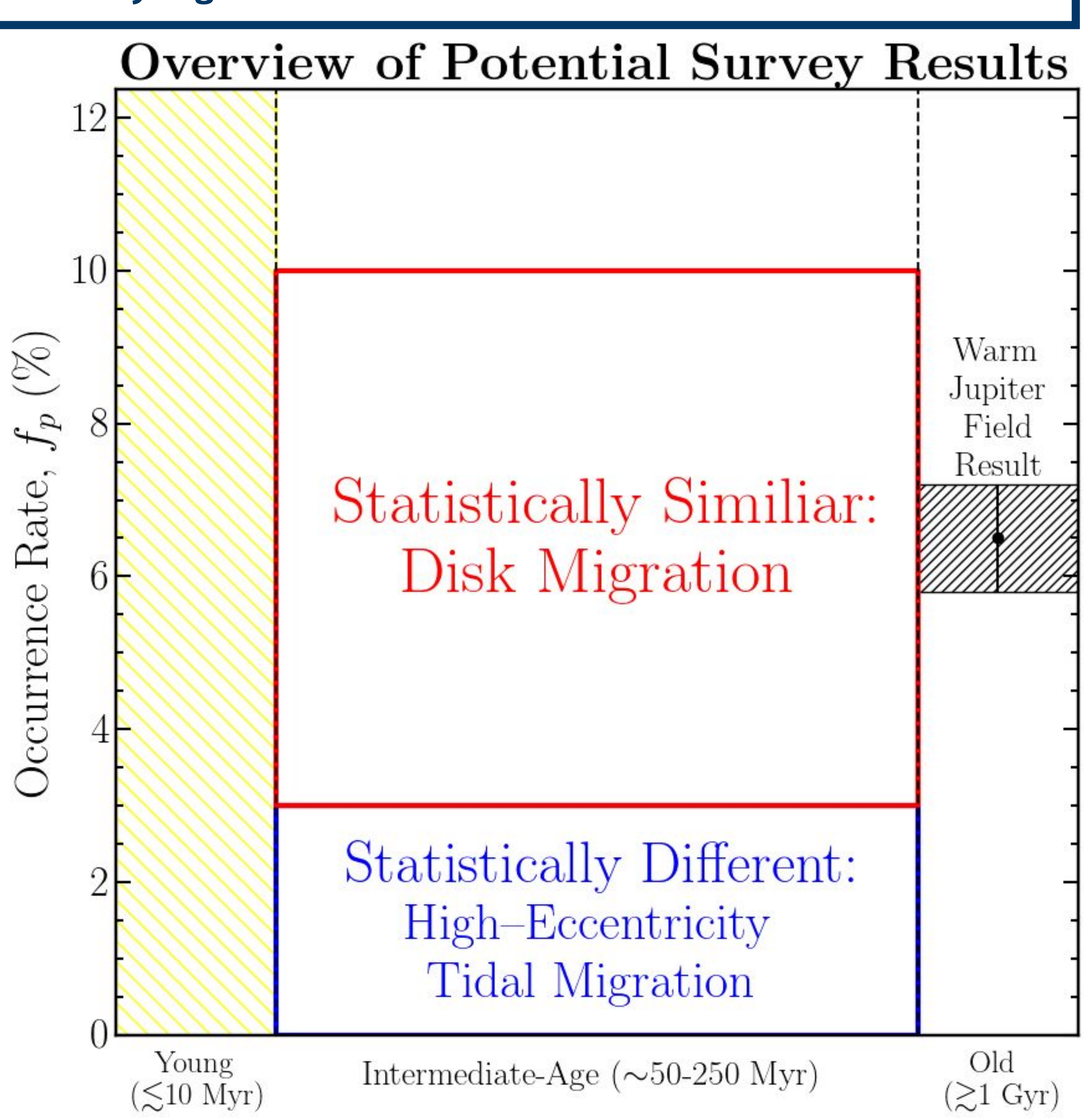


Fig. 2: 2 survey results are possible. If we find a statistically similar occurrence rate, this suggests that disk migration is dominant. If we find a statistically distinct result, then three-body dynamical interactions likely dominates.

YOUNG PLANETS & THE NEAR-INFRARED ADVANTAGE

> By **measuring the young giant planet occurrence rate**, we can compare it to older populations to determine the dominant migration pathway.

> Young stars have been avoided because they are intrinsically active and contribute significant non-dynamical astrophysical noise (as high as ~100 m/s in the optical for a 50 Myr star[1]).

> Moving to the NIR has been shown to reduce these effects by a factor of ≈2-3 for young T Tauri stars (50 Myr).[2]

> Focusing on intermediate age (~20-200 Myr) stars can further reduce this activity, opening the possibility of detecting young planets.

SURVEY DESIGN

> **9 Young Moving Groups** (AB Dor, β Pic, Carina, Carina-Near, Octans, Tuc-Hor, Pleiades, 32 Ori, and Pisces)

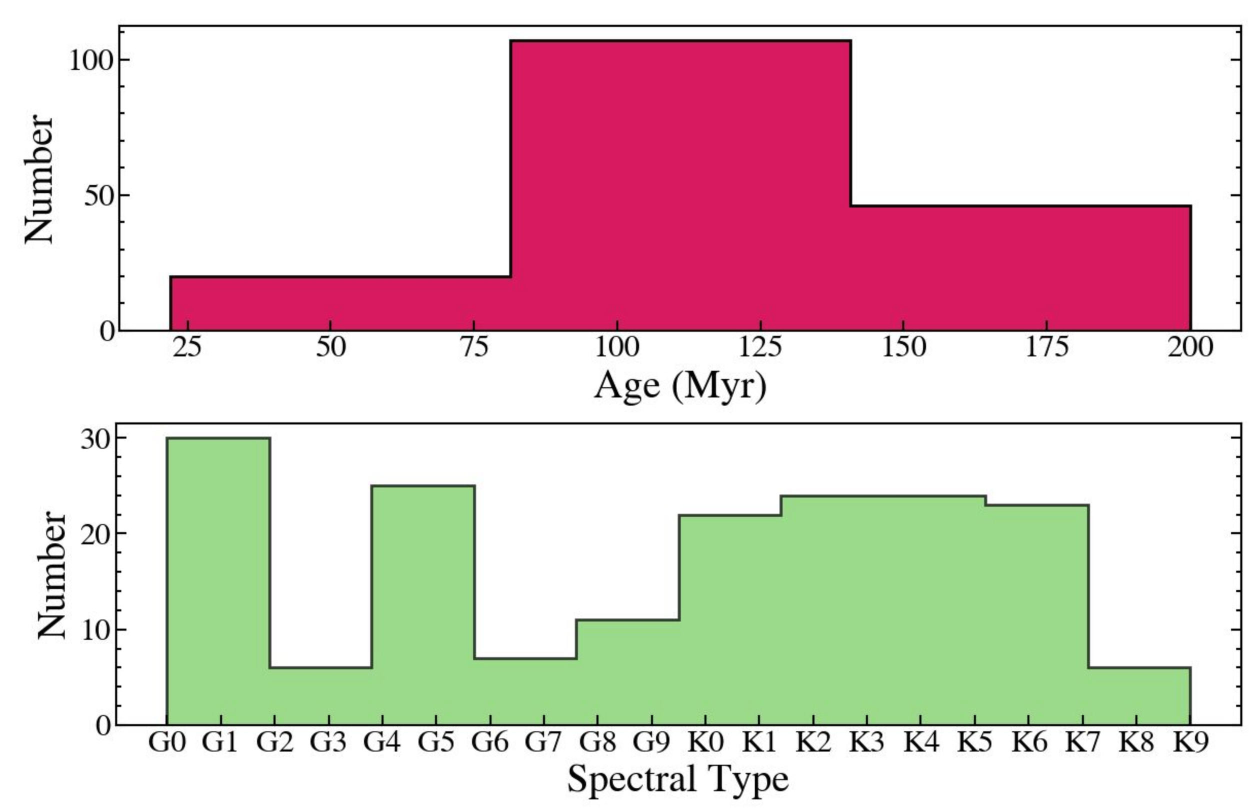
> **~110 Targets** in final sample

> **~20 - 200 Myr** Intermediate age stars to compare to both very young (~10 Myr) and field (≥1 Gyr) stars

> **4 year, 2.5 AU Baseline,** to reach out to the Ice-line of GK stars

> **HPF** is a fiber-fed, temperature stabilized (*T*~180K), NIR (810-1280 nm), high-resolution (*R*~55,000) precision spectrograph, reaching ~1.5 m/s stability[3]. It is located at the 10m Hobby-Eberly Telescope (HET) and uses queue scheduling.[4]

> Targets are vetted for spectroscopic binaries, close visual binaries, and fast rotators (> 30 km/s)



SURVEY STATUS

> All targets already have first epochs

> ≥29 targets already have >3 epochs

> Instrument + pipeline achieving 1.7 m/s precision with PRV standard, similar to measurements found in optical wavelengths

> ~115 hours, or ~11.5 nights thus far awarded

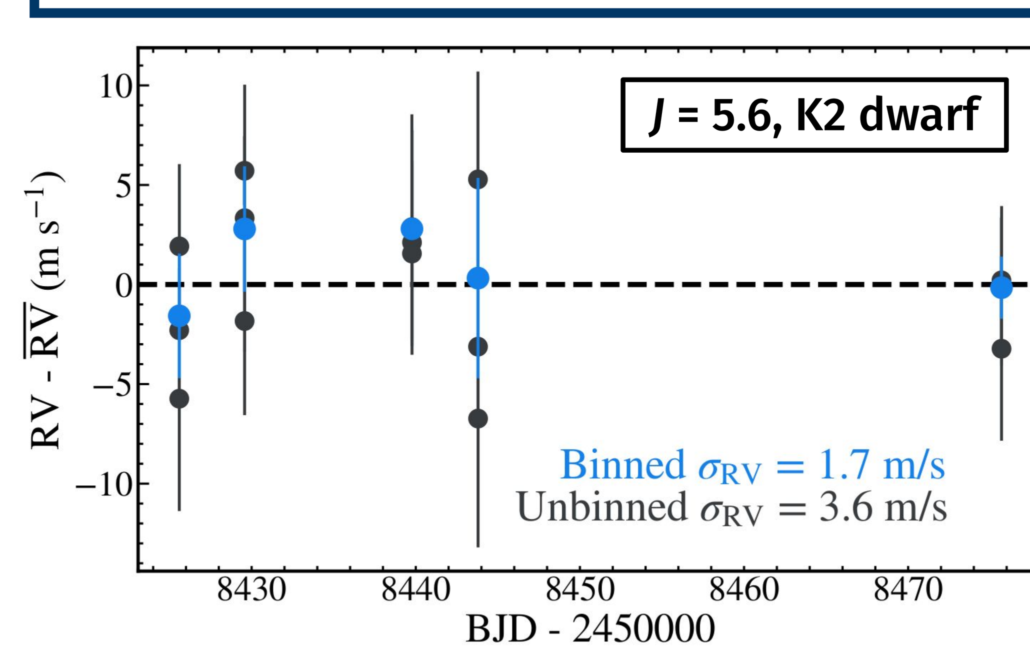


Fig. 4: RV measurements for K-dwarf PRV standard HD 3765. Using 5 epochs, a binned RMS of σ_{RV} = 1.7 m/s is found, similar to measurements in the optical.[4]

PRV PIPELINE

1. A median template is generated:
   a. **Corrects for barycentric motion** in all science spectra
   b. **Scales to highest SNR** spectra using low-order polynomial
   c. **Performs B-spline regression** through all spectra data
   d. **Downweights tellurics and sky emission lines** (not mask)
2. Calculates RV using least-squares matching (χ^2) algorithm
   a. **Explicitly masks out tellurics and sky emission lines** in median master template

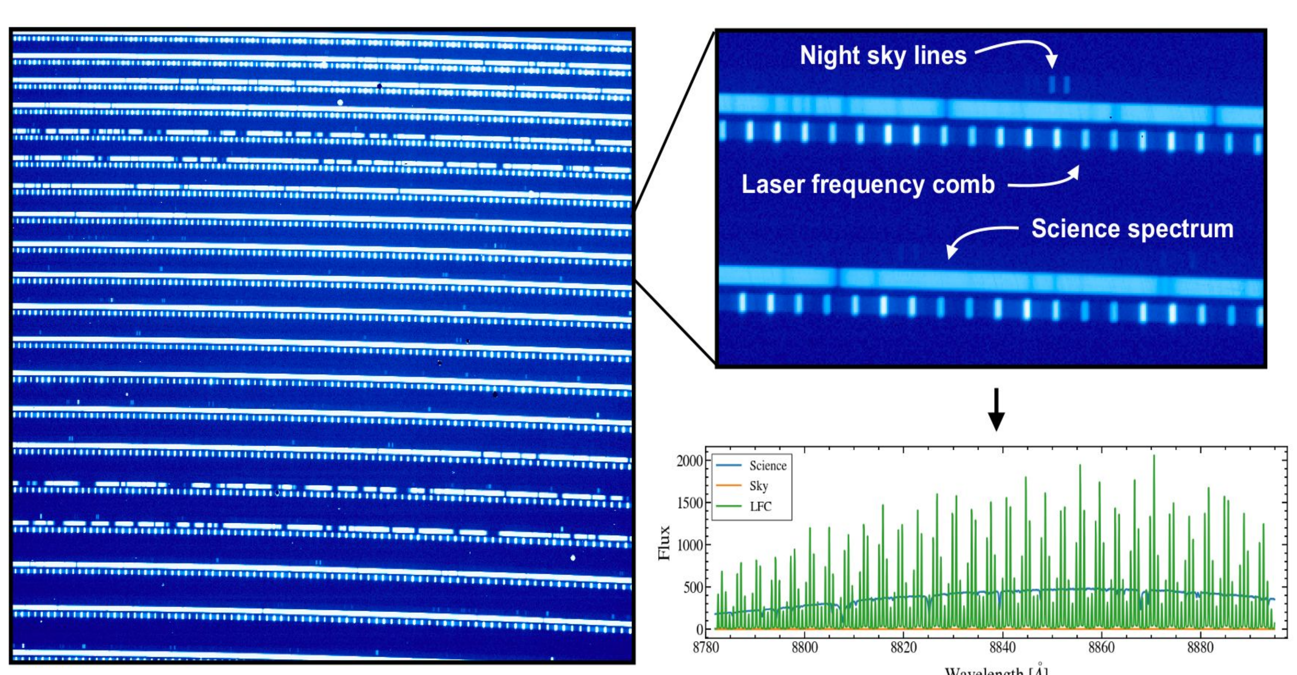


Fig. 5: Example of on-sky observations with HPF from our survey. Each order simultaneously disperses three fibers: the sky, the science target, and the laser frequency comb. 1D spectra and optimally extracted and wavelength calibrated using the regularly-spaced laser frequency comb emission peaks.

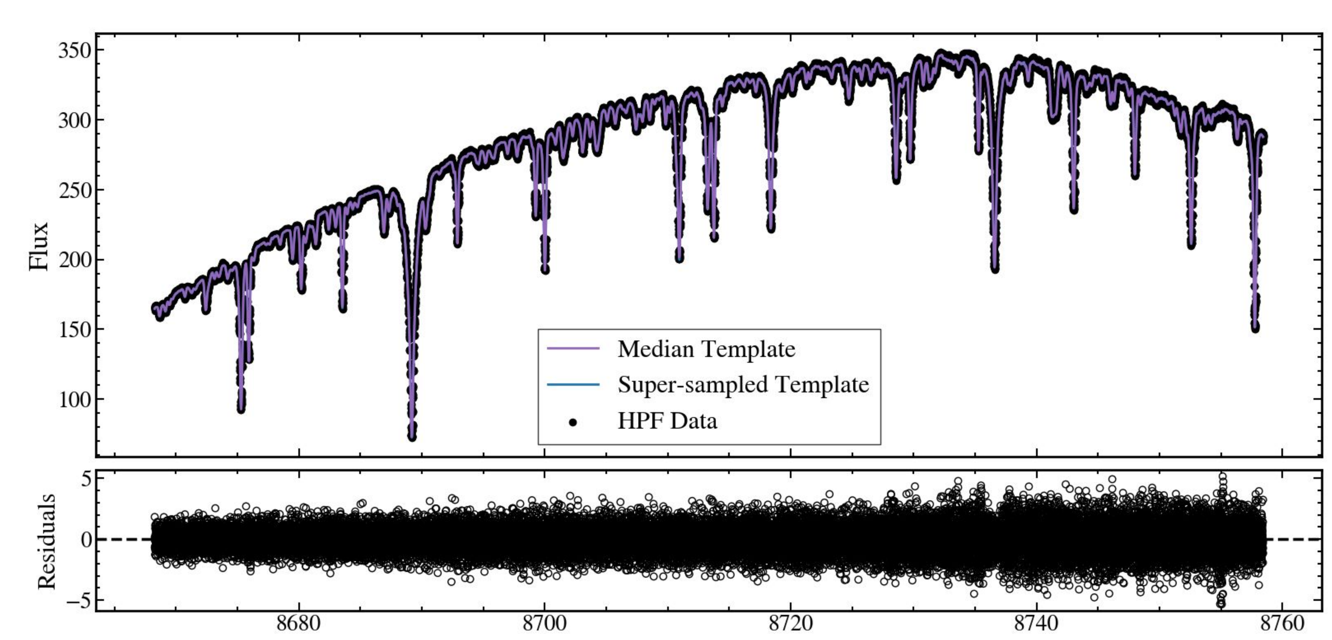


Fig. 6: Example of the master median template generated by the RV pipeline. Black points are the scaled, corrected data, while the purple line is the template used to measure an RV.

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