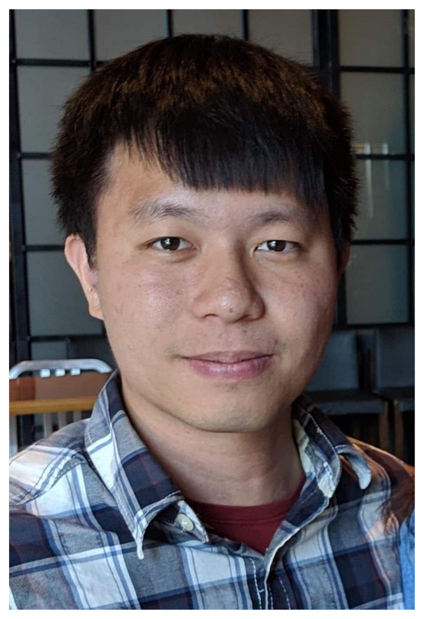

Precise Radial and Rotational Velocities for T Dwarfs Using NIRSPEC High-Resolution Spectrometer

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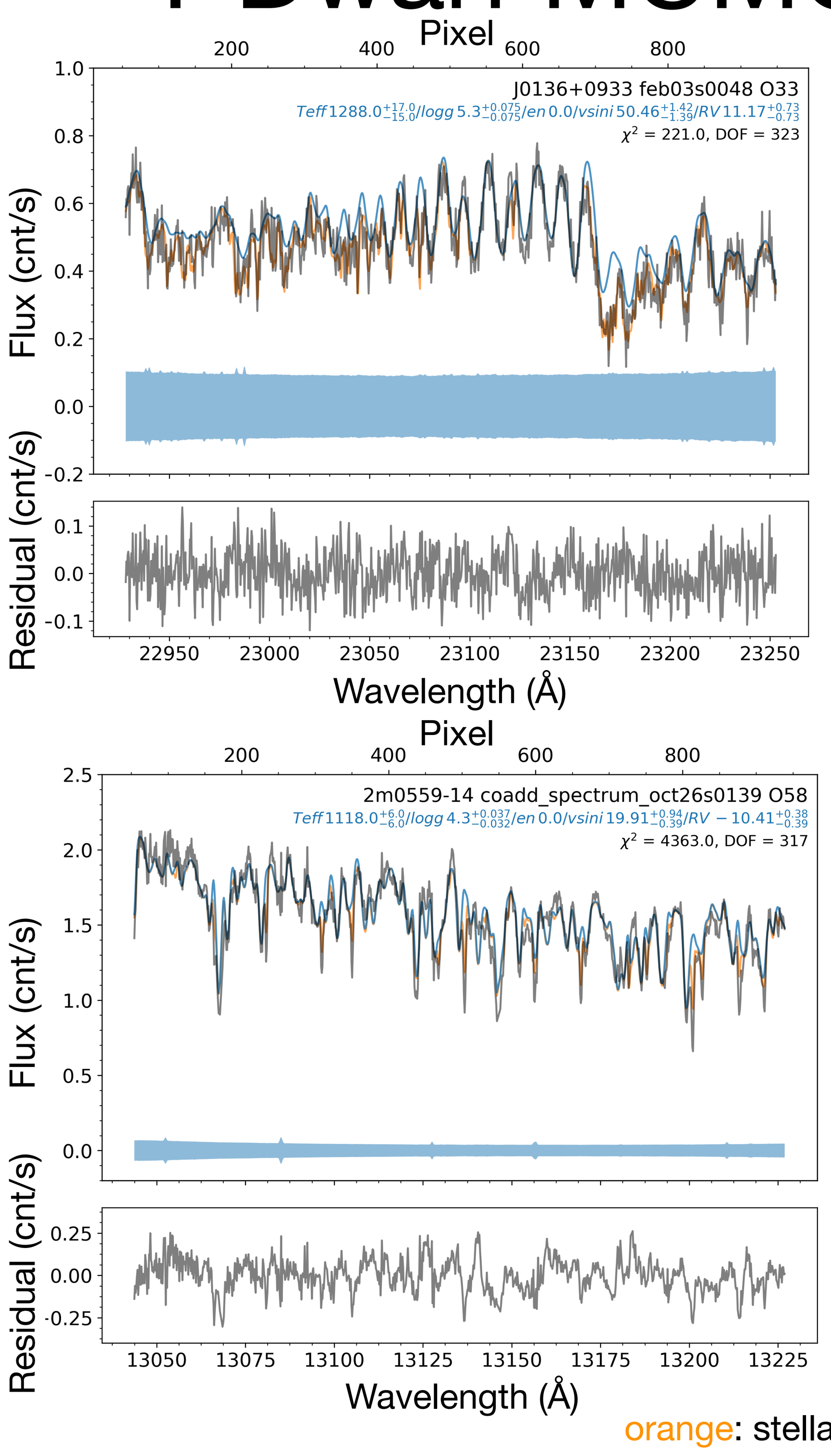
Introduction

Precise measurements of radial (RV) and rotational (vsini) velocities of stars are essential for studying stellar kinematics, binary orbits, and rotational dynamics for intrinsically faint ultracool dwarfs: stellar and sub-stellar objects with effective temperatures less than 3,000 K. Due to their low temperatures, 3D velocity samples of these objects are correspondingly small. We are conducting a radial velocity survey of over 300 late-M, L, T dwarfs, drawing from nearly twenty years of archival high-resolution data from the Keck NIRSPEC near-infrared spectrometer, reduced by the NIRSPEC Data Reduction Pipeline. We determine RV, vsini, and atmospheric parameters using a Markov Chain Monte Carlo (MCMC) forward modeling method. Here we present our analysis of the T dwarf sample. We compare our RV and vsini measurements to prior measurements, examine the distributions in atmospheric parameters (Teff, logg), and search for radial velocity variables. We also compute their Galactic *UVW* velocities and statistical kinematic ages distribution.

T Dwarf MCMC Fits

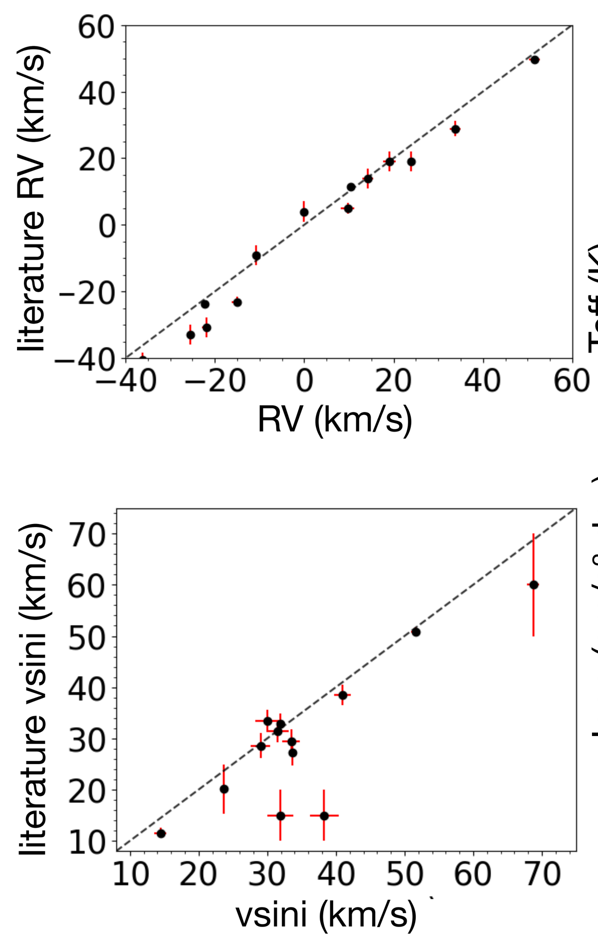


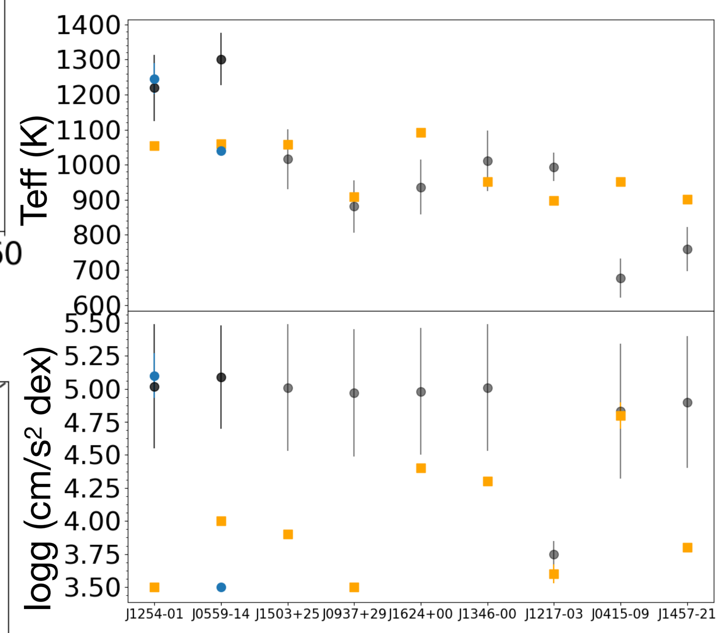
orange: stellar model
blue: stellar model x telluric absorption
black: observed spectra

We built upon the forward modeling method[5,7]. The BT-Settl atmosphere model[1] is RV-shifted and convolved with a stellar rotation kernel, then multiplied by the telluric absorption, convolved with the instrumental broadening kernel, and finally corrected by the continuum. We employed the MCMC to extract the effective temperature, gravity, vsini, RV, and telluric absorption alpha parameters.

Measurement Precision

Our RV and vsini measurements are generally consistent with previous results, with **median precisions of 0.9 and 1.5 km/s**, respectively. Our RV precision is best for smaller vsini and higher S/N.

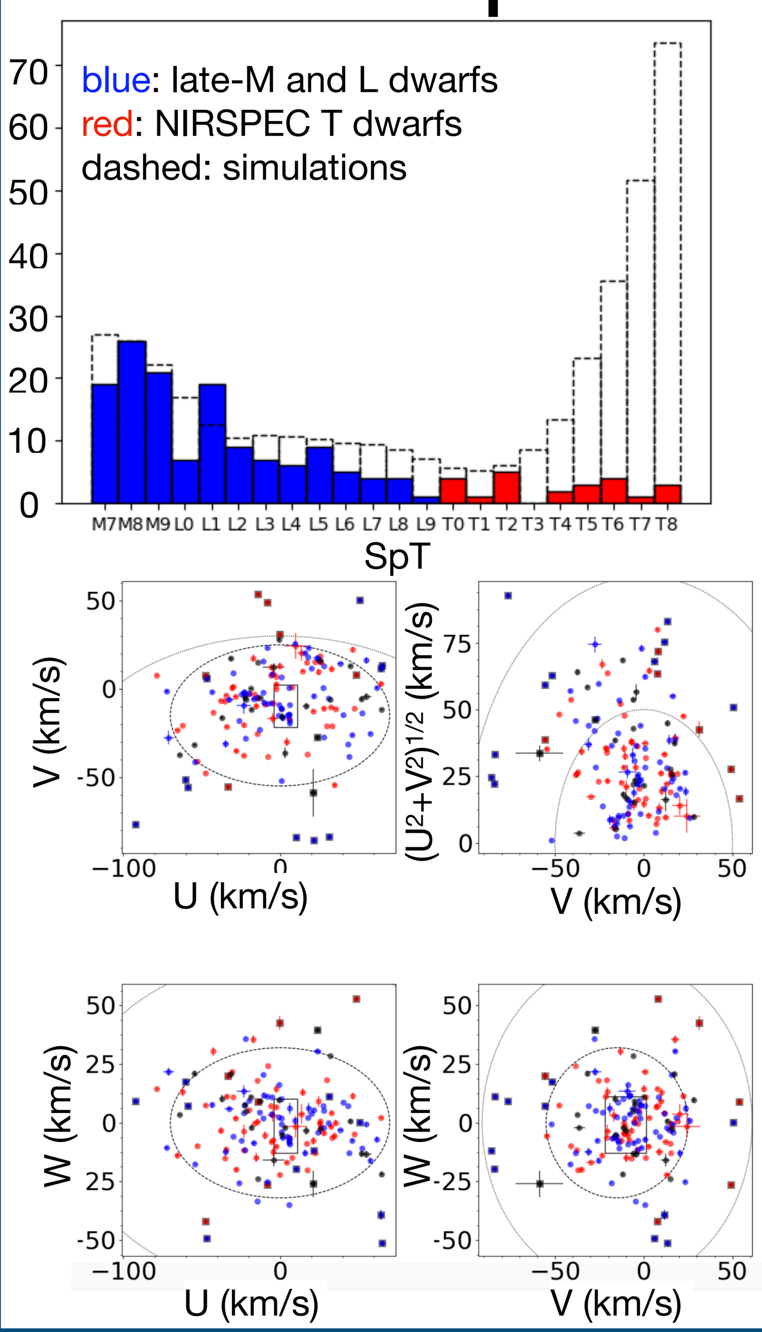




orange: order 58
blue: order 33
black: Filippazzo et al. (2015)

Our Teff decreases with later spectral type, but with a much shallower slope compared to [8], whereas later spectral types are best-fit with higher logg but generally lower than [8].

UVW Space Motions



We computed the Galactic *UVW* space motions of T dwarfs by combining proper motions and parallaxes[11]. A local precise RV (d <= 20 pc, σ_{RV} <= 3 km/s) sample of late-M and L dwarfs was compiled from the literature. Small correlations of UV velocities are found for the late-M and L dwarfs, stronger negative UW correlation was found for the T dwarfs. **The L dwarfs are kinematically more dispersed.**

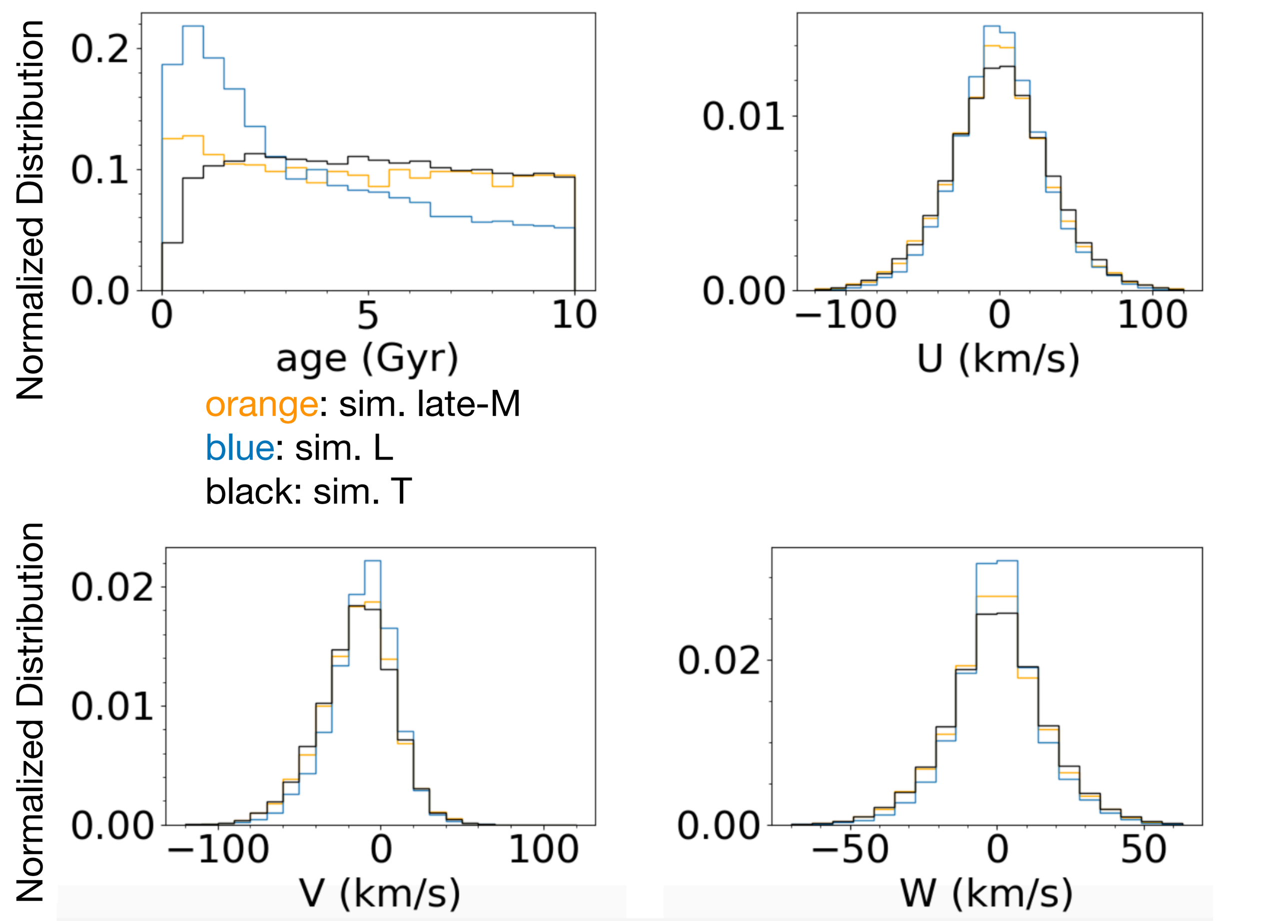
red: late-M dwarfs
blue: L dwarfs
black: T dwarfs
circles: 2 σ uncertainty for the thin and thick disk populations[4]
box: a good box for YMGs[12]

UCD Kinematic Ages

The velocity dispersion of a stellar population is related to the age of a population due to dynamical heating and increasing Galactic scale heights and relative velocities over time. The Kinematic ages can be computed[2] from these dispersions. The ages for the late-M and T dwarfs are comparable, while the **L dwarf population appears too old**. A population simulation was conducted for the late-M, L, and T dwarfs. We assumed a uniform star formation rate from 0.1 to 10 Gyr and a mass range from 0.01 to 0.20 M_{sun}. We used an evolutionary model[3] to convert the age and mass to Teff relation, and an empirical relation to convert Teff to spectral type[8].

Sample	N	$\langle U \rangle$ (km s^{-1})	$\langle V \rangle$ (km s^{-1})	$\langle W \rangle$ (km s^{-1})	Age Gyr
Observed late-M dwarfs	63	-3.697 ± 0.017	-4.503 ± 0.017	0.99 ± 0.02	4.1 ± 0.2
Simulated late-M dwarfs	···	-0.6 ± 0.4	-14.8 ± 0.3	-0.3 ± 0.2	4.6 ± 0.2
Observed L dwarfs	70	1.596 ± 0.011	-10.616 ± 0.012	-2.29 ± 0.01	5.6 ± 0.3
Simulated L dwarfs	···	0.3 ± 0.3	-11.5 ± 0.2	0.27 ± 0.15	3.43 ± 0.18
Observed T dwarfs	22	2.1 ± 0.1	-9.1 ± 0.1	2.4 ± 0.1	4.7 ± 0.5
Simulated T dwarfs	···	0.2 ± 0.2	-15.24 ± 0.14	0.0 ± 0.1	4.9 ± 0.2

Table 1. Observed and simulated kinematic ages of UCDs.



Key Take-Aways

- We present NIRSPEC measurements of precise RV and vsini for 22 T dwarfs (median uncertainty of 0.9 and 1.5 km/s), also with the corresponding Teff and logg.
- We compiled a sample of 63 late-M and 70 L dwarfs within 20 pc with RV precision less than 3 km/s to assess their UVW space motions and kinematic ages.
- The derived L dwarf kinematic age appears to be too old (5.6 ± 0.3 Gyr) compared to the simulation (3.43 ± 0.18 Gyr), whereas the kinematic ages of late-M (4.1 ± 0.2 Gyr) and T dwarfs (4.7 ± 0.5 Gyr) are younger and consistent with the simulation.

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