Radial Velocities and Kinematic Ages of Nearby T Dwarfs from Keck/NIRSPEC High-Resolution Spectroscopy

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Introduction

Precise measurements of radial (RV) and rotational (*vsini*) velocities of stars are essential for studying stellar kinematics (space velocities and dispersions), binary orbits (mass measurements and formation), and rotational dynamics (angular momentum evolution). The high-resolution spectroscopic observations necessary to make these measurements are challenging for the intrinsically faint and low-temperature ultracool dwarfs, stellar and sub-stellar objects with masses below 0.1 $M_\odot$. Previous local UCD kinematic studies indicated conflicting L dwarf kinematic ages[5,6,10,15], with little constraints on the T dwarf kinematic due to smaller sample size (N = 9)[15]. We present a radial and rotational velocity survey of 37 nearby (d ≤ 20 pc) T dwarfs based on forward-modeling analysis of nearly 20 years of high-resolution spectra obtained with Keck/NIRSPEC.

Modeling the Spectral Data

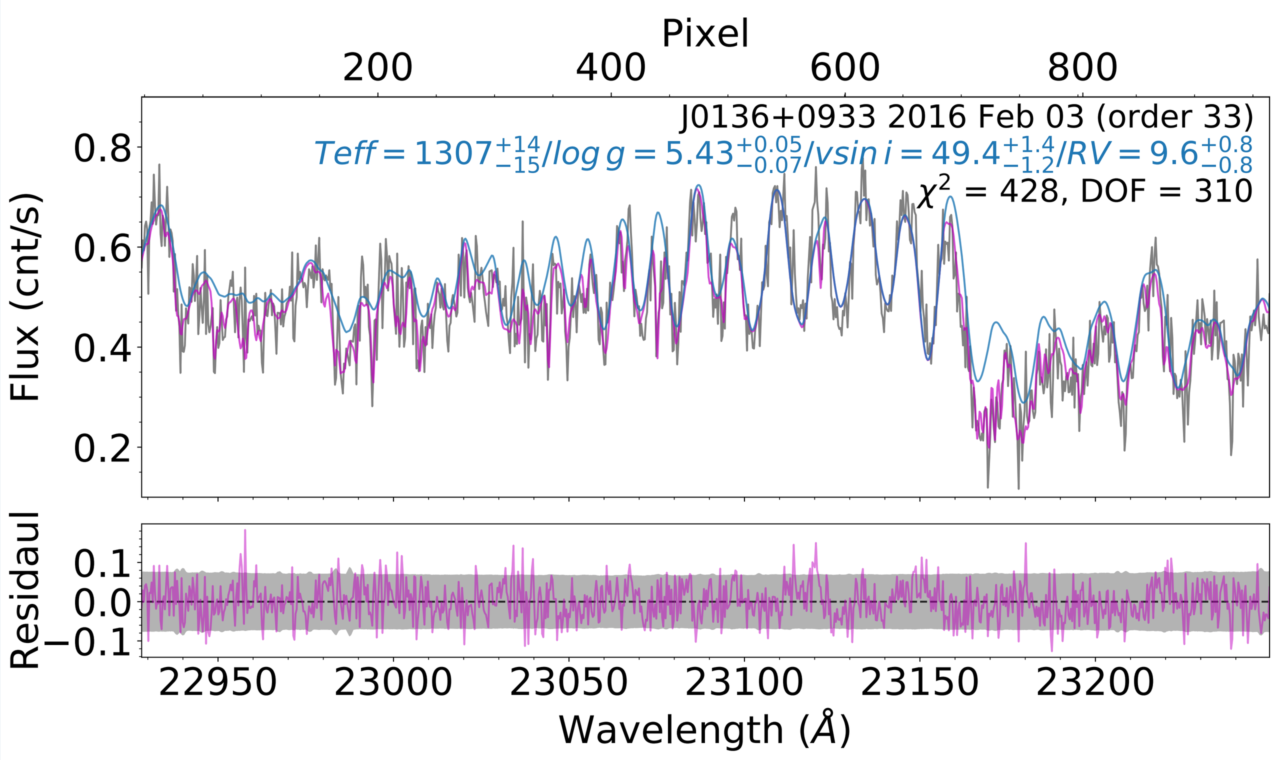

Figure 1. BT-Settl model fit of the order 33 spectrum of the T2.5 J0136+0933, observed on 2016 February 3 (UT). *Upper*: the grey line is the observed spectra; the magenta and blue lines are the stellar model with and without telluric absorption, respectively. *Lower*: difference of the data - model (magenta) with ±1σ data uncertainty shaded in grey.

We built upon the forward modeling method[5,7] and employed MCMC to extract the effective temperature, gravity, *vsini*, RV, telluric airmass and water vapor parameters (Figure 1). Based on our analysis of 37 T dwarfs, our RV and *vsini* measurements are generally consistent with previous results, and we achieve **median precisions of 0.5 and 0.9 km/s**, respectively. RV precision is better for late-M/L dwarfs as they typically have higher S/N and smaller *vsini* values.

UCD Kinematics & Ages

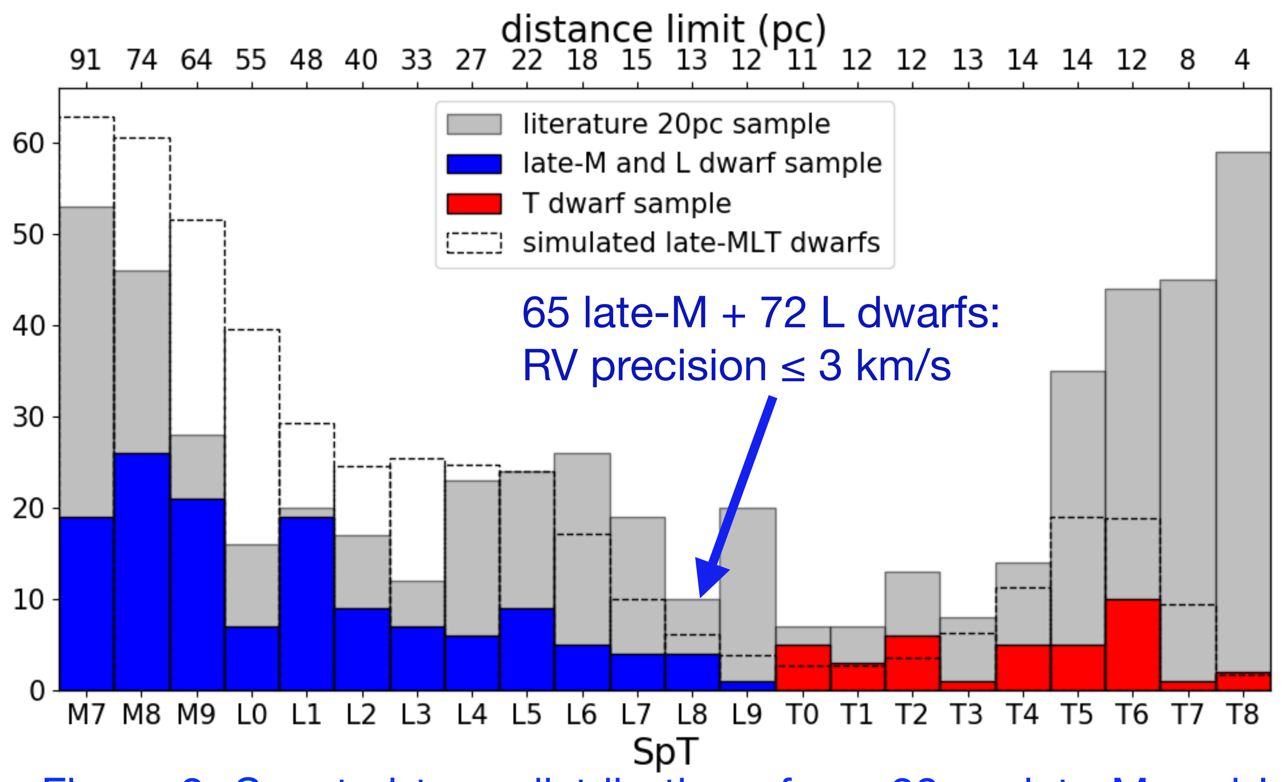

Figure 2. Spectral type distribution of our 20 pc late-M and L dwarf kinematic sample with RV uncertainty of ≤ 3 km s^{-1} (blue histogram), and our NIRSPEC T dwarf sample (red histogram).

Kinematic ages were computed[2] from empirical age-velocity dispersions for a local sample of 173 UCDs with RV uncertainty ≤ 3 km s^{-1} (Figure 2). The estimated ages for the late-M and T dwarfs are comparable (4.1 ± 0.3 Gyr and 3.5 ± 0.3 Gyr), while the L dwarf population appears too old (5.7 ± 0.3 Gyr). However, the local L dwarf sample has a higher fraction of thick disk sources, and **removing them brings the L dwarf age into alignment (4.1 ± 0.3 Gyr), resolving a decade-old mystery**. A population simulation assuming an exponential star formation rate[2] from 0.1 to 9 Gyr and a mass range from 0.01 to 0.15 $M_\odot$ predicts ages consistent with the measurements (Figure 3).

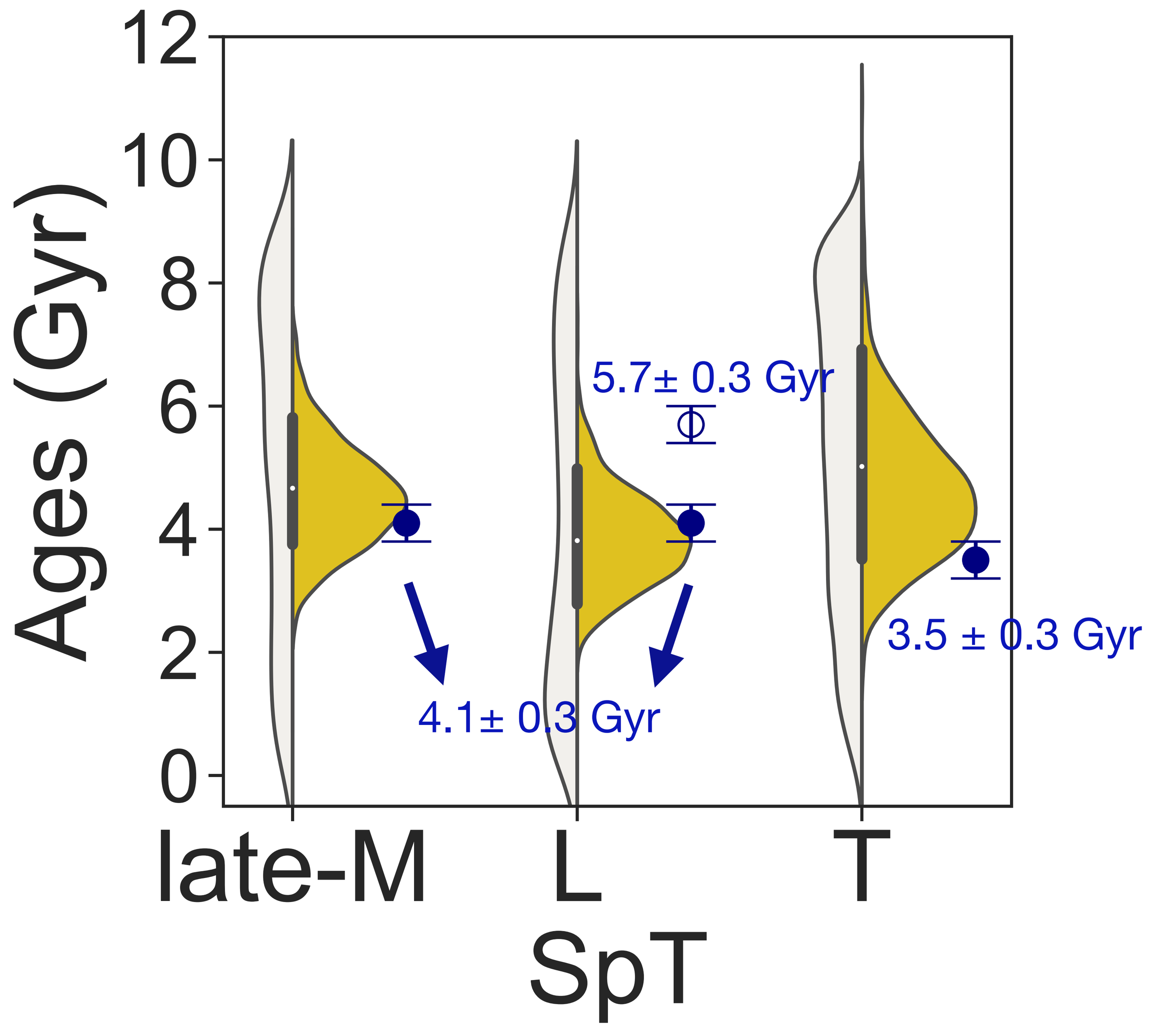

Figure 3. Simulated age distributions (white/yellow violin plots for individual/inferred ages, respectively) and measured kinematic ages for late-M, L, T dwarfs. The L dwarf age with thick disk sources included is indicated by the open circle.

Kinematic H Burning Limit

A kinematic dispersion break is found around the L4–L6 subtypes, which likely reflects the terminus of the stellar Main Sequence (Figure 4), consistent with dynamical mass determinations[9] but later than radius measurements[8].

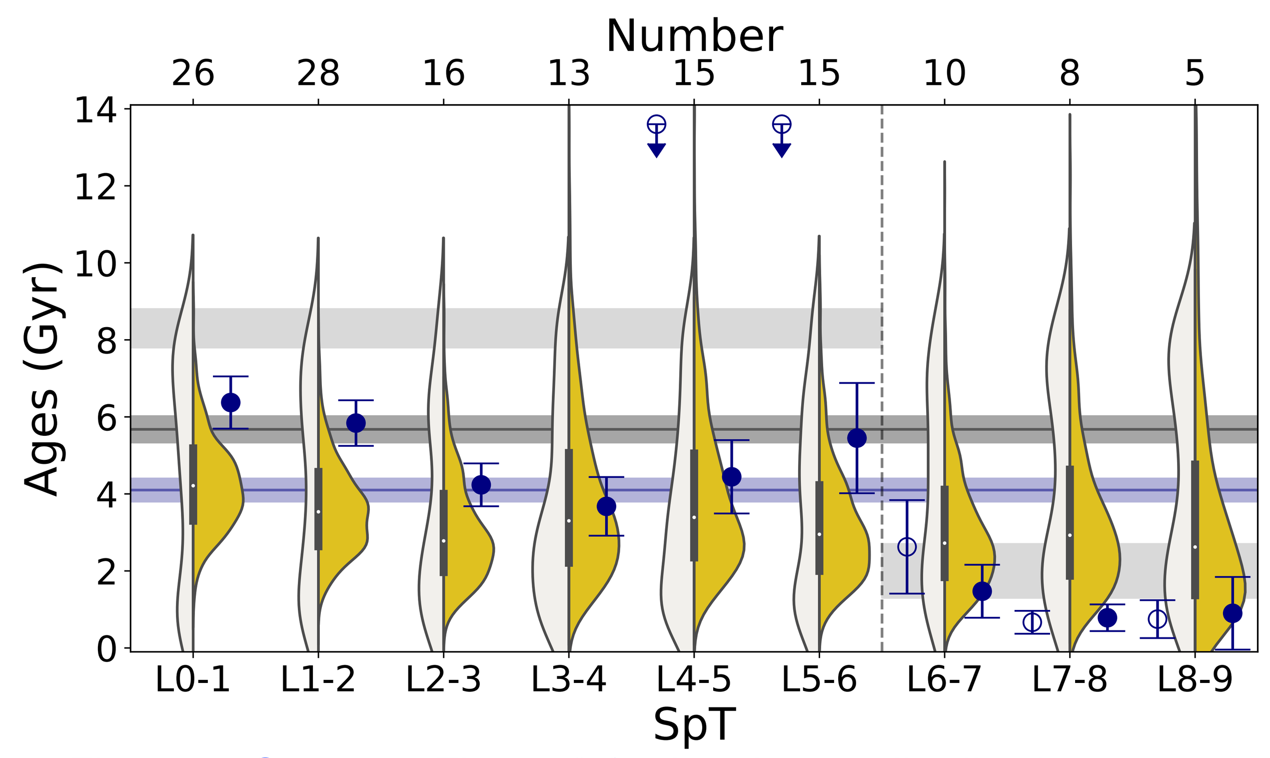

Figure 4. Same as Figure 3 for L subtype distributions.

UCD vsini Distribution

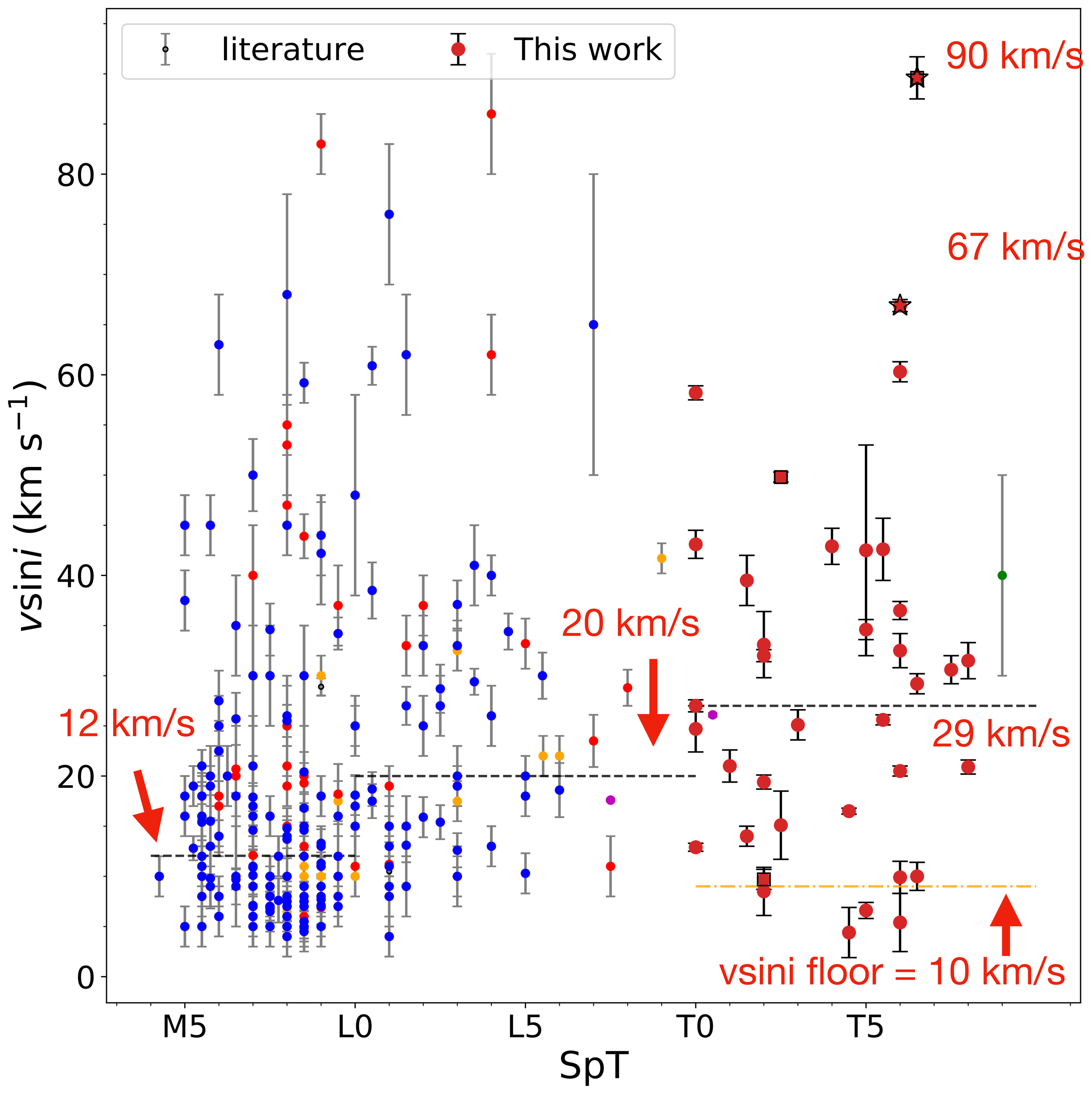

Figure 5. *vsini* measurements as a function of spectral type for a compilation of M4–T9 dwarfs from this work (large symbols) and the literature (small symbols).

We compare *vsini* measurements for M4–T9 dwarfs and our 37 T dwarfs (red circles) in Figure 5. The median *vsini* values increase with later spectral types. The young and fastest T dwarfs are labeled in squares and stars, respectively. T dwarfs are generally fast rotators, indicating little angular momentum loss compared to earlier spectral types.

Acknowledgements

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