

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



Dino Chih-Chun Hsu<sup>1</sup>(chh194@ucsd.edu), Adam Burgasser<sup>1</sup>, Christopher Theissen<sup>1</sup>, Christopher Gelino<sup>2</sup>, Jessica Birky<sup>1</sup>, Sharon Diamant<sup>3</sup>, Daniella Bardalez Gagliuffi<sup>3</sup>, Christian Aganze<sup>1</sup>, Cullen Blake<sup>3</sup>

1. UC San Diego 2. IPAC/Caltech 3. University of Washington 4. Leiden Observatory 5. American Museum of Natural History 6. University of Pennsylvania

## Introduction

Precise measurements of radial (RV) and rotational ( $v \sin i$ ) 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<sup>5,6,10,15</sup>, with little constraints on the T dwarf kinematic due to smaller sample size ( $N = 9$ )<sup>15</sup>. We present a radial and rotational velocity survey of 37 nearby ( $d \leq 20$  pc) T dwarfs based on forward-modeling analysis of nearly 20 years of high-resolution spectra obtained with Keck/NIRSPEC.

## Modeling the Spectral Data

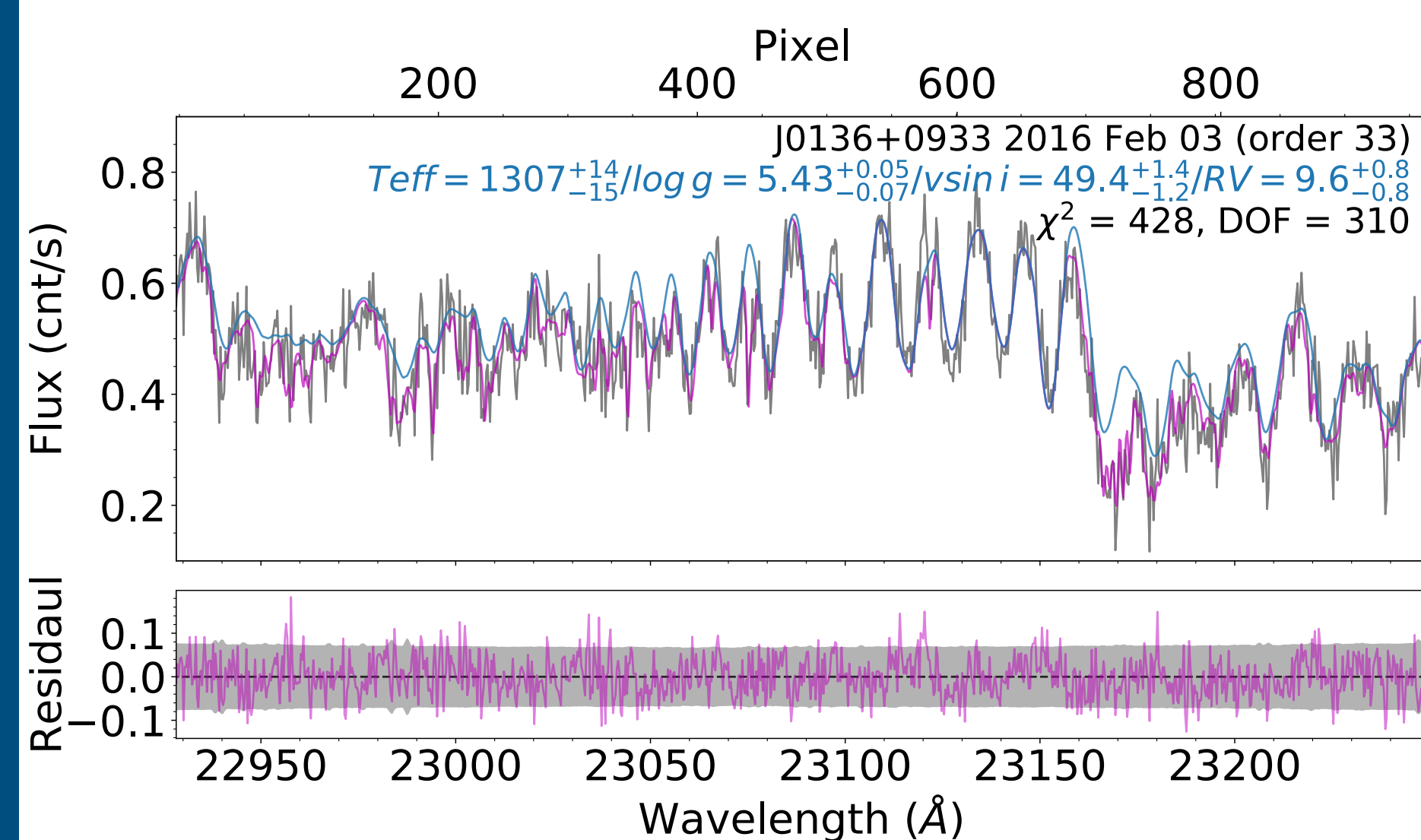


Figure 1. BT-Settl model fit of the order 33 spectrum of the T2.5 J0136+0933, observed on 2016 February 3 (UT). Upper: the grey line is the observed spectra; the magenta and blue lines are the stellar model with and without telluric absorption, respectively. Lower: difference of the data - model (magenta)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

We built upon the forward modeling method<sup>5,7</sup> and employed MCMC to extract the effective temperature, gravity,  $v \sin i$ , RV, telluric airmass and water vapor parameters (Figure 1). Based on our analysis of 37 T dwarfs, our RV and  $v \sin i$  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  $v \sin i$  values.

## UCD Kinematics & Ages

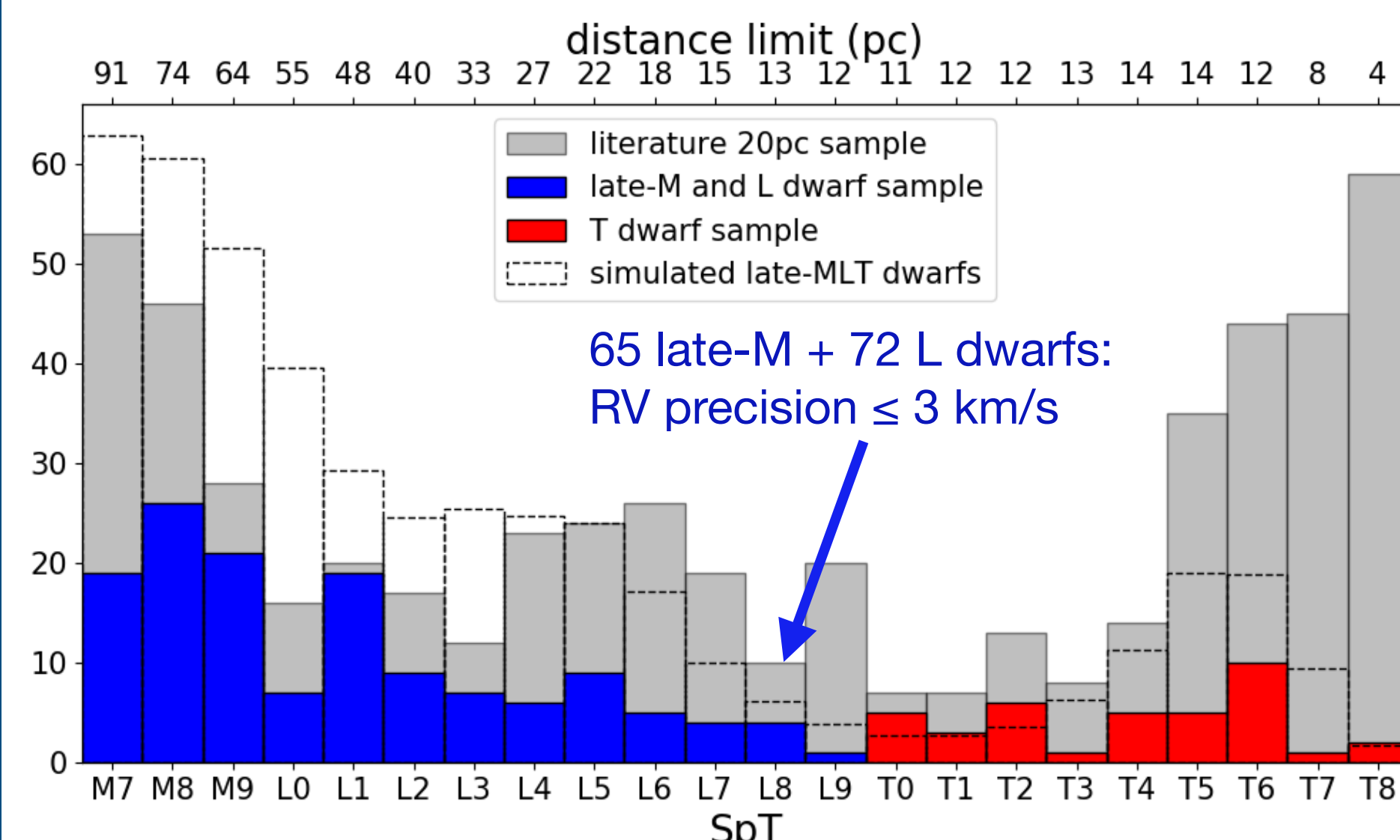


Figure 2. Spectral type distribution of our 20 pc late-M and L dwarf kinematic sample with RV uncertainty  $\leq 3 \text{ km s}^{-1}$  (blue histogram), and our NIRSPEC T dwarf sample (red histogram).

Kinematic ages were computed<sup>2</sup> from empirical age-velocity dispersions for a local sample of 173 UCDs with RV uncertainty  $\leq 3 \text{ km s}^{-1}$  (Figure 2). The estimated ages for the late-M and T dwarfs are comparable ( $4.1 \pm 0.3 \text{ Gyr}$  and  $3.5 \pm 0.3 \text{ Gyr}$ ), while the L dwarf population appears too old ( $5.7 \pm 0.3 \text{ Gyr}$ ). However, the local L dwarf sample has a higher fraction of thick disk sources, and **removing them brings the L dwarf age into alignment ( $4.1 \pm 0.3 \text{ Gyr}$ ), resolving a decade-old mystery**. A population simulation assuming an exponential star formation rate<sup>2</sup> 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).

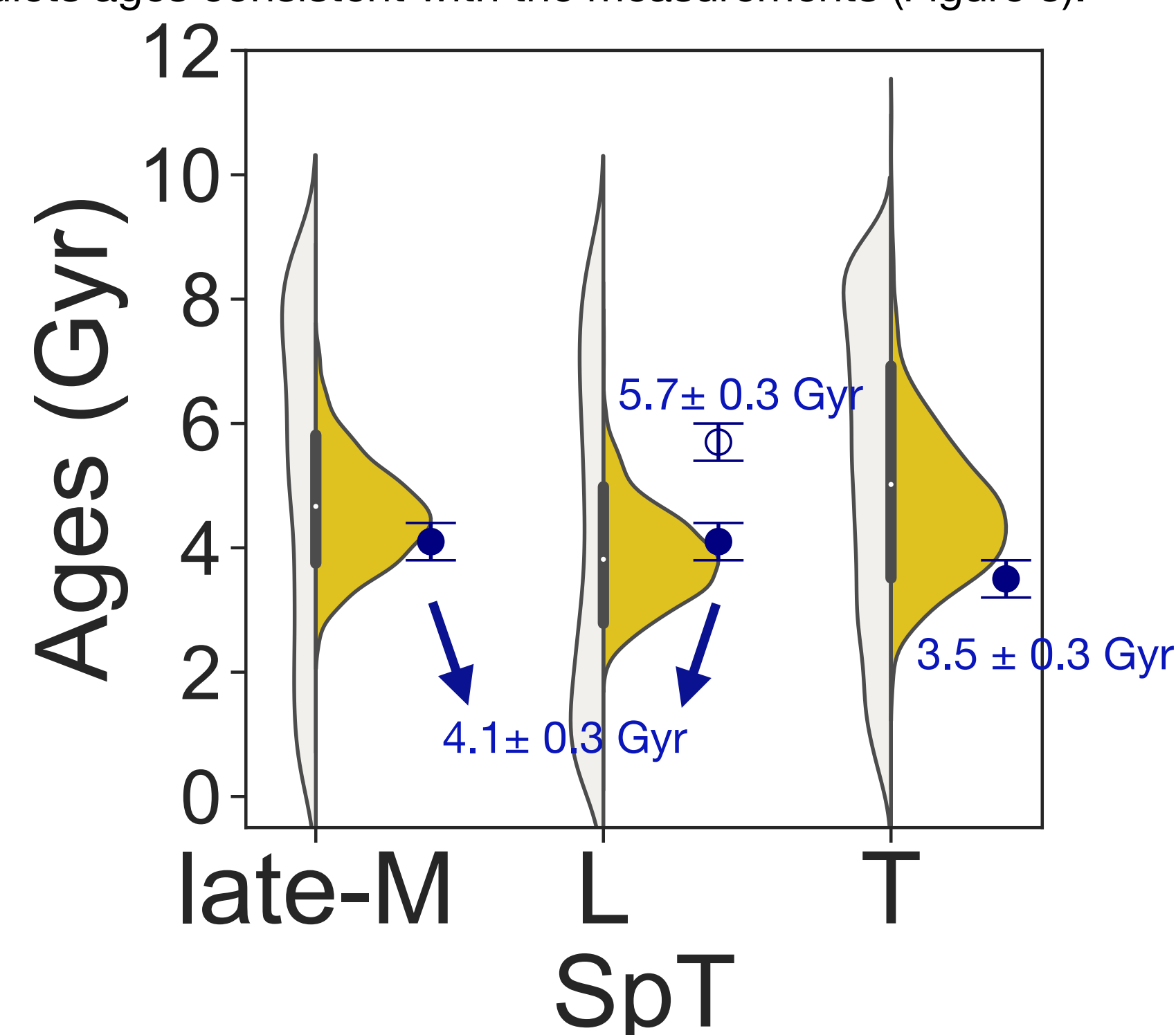


Figure 3. Simulated age distributions (white/yellow violin plots for individual/inferred ages, respectively) and measured kinematic ages for late-M, L, T dwarfs. The L dwarf age with thick disk sources included is indicated by the open circle.

## 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<sup>9</sup> but later than radius measurements<sup>8</sup>.

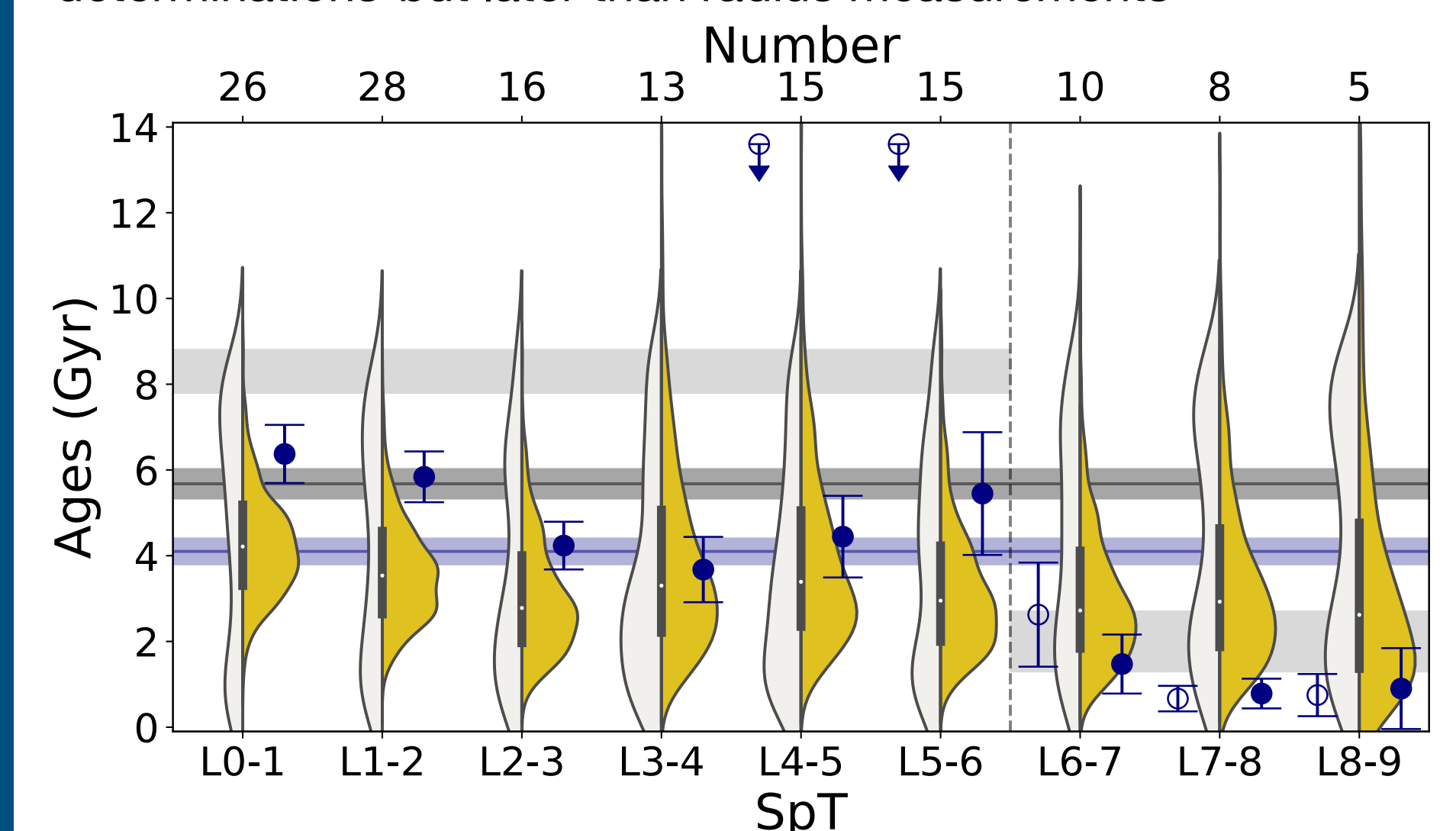


Figure 4. Same as Figure 3 for L subtype distributions.

## UCD $v \sin i$ Distribution

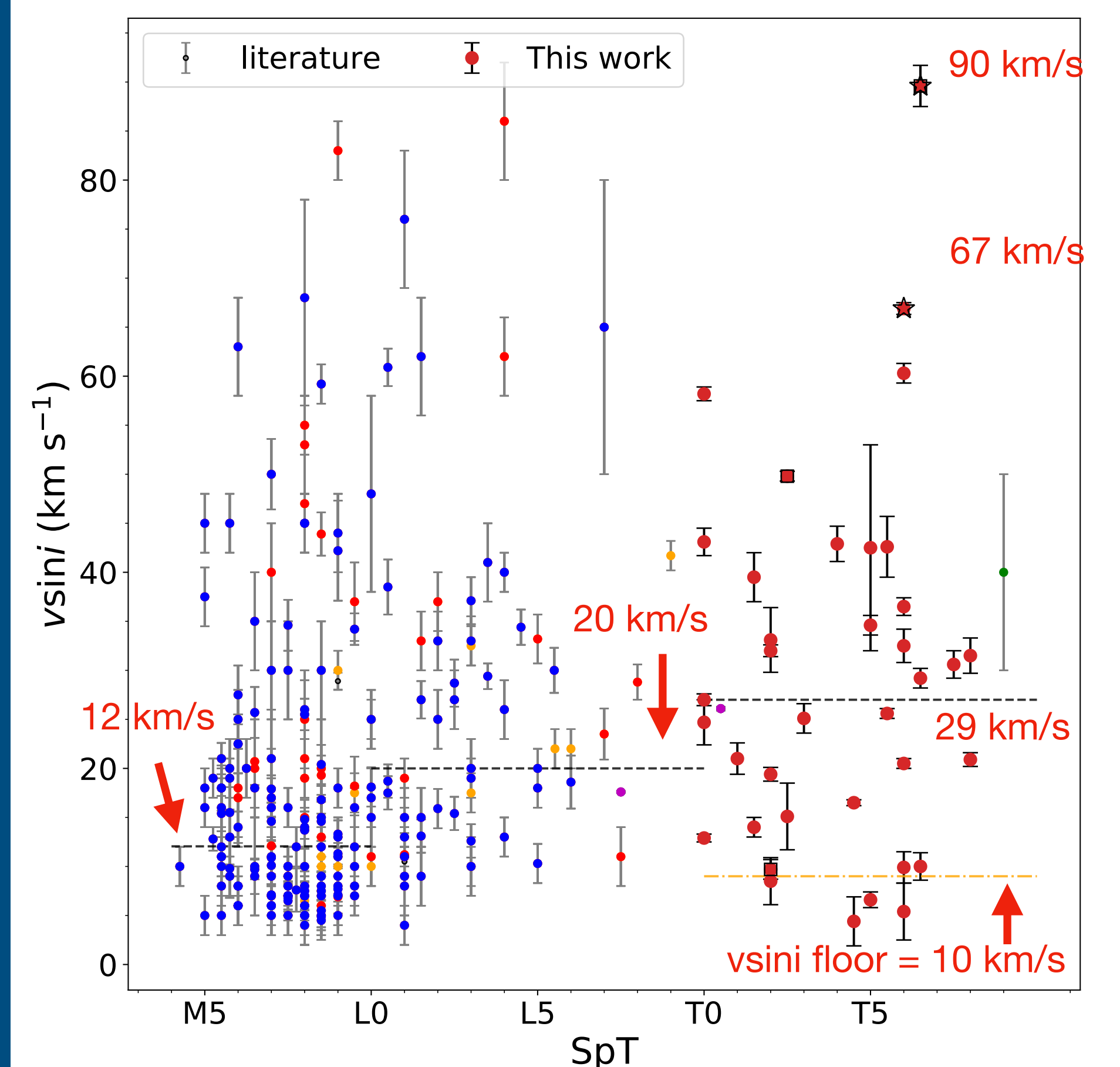


Figure 5.  $v \sin i$  measurements as a function of spectral type for a compilation of M4–T9 dwarfs from this work (large symbols) and the literature (small symbols).

We compare  $v \sin i$  measurements for M4–T9 dwarfs and our 37 T dwarfs (red circles) in Figure 5. The median  $v \sin i$  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

## References

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