



# The Effect of Atmospheric Cooling on the Galactic Distributions of Brown Dwarfs

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## 1. Motivation:

Stars form in thin disk, then scatter off of disk objects (e.g. molecular clouds) to attain large vertical velocities (so-called *disk heating*). Brown dwarfs are born with some temperature and cool throughout their lifetime, therefore hot brown dwarfs (~2500K) are expected to be young and reside in a thin disk. Whereas cool brown dwarfs (~1000K) may be a combination of old (and massive) and young (and low mass) dwarfs, and in a thicker disk. Therefore the properties of the brown dwarf disk may hold clues to the physics of their atmospheric cooling.

## 2. The Catch:

Kinematic studies find a wide range of (vertical) velocity dispersions for mid-L dwarfs — some estimates are less than that of M-dwarfs, some are higher. If the higher estimates are accurate, then the reconciliation is either:

- **astrophysical:** star-formation history where brown dwarfs are preferentially formed at early times, while stars are formed constantly; or
- **data:** kinematic studies will be more sensitive to high velocity objects and/or possible pathology in the samples of nearby brown dwarfs.

Therefore we present a Monte Carlo simulation to address this contradiction and predict an alternative method to explore the same stellar and Galactic physics.

## 3. Monte Carlo Simulation:

Distribute  $10^9$  stars according to realistic distributions:

$$\phi(m; \alpha) dm \propto m^{-\alpha} dm,$$

$$\psi(t; \beta, \tau) dt \propto \left(\frac{t}{\tau}\right)^\beta \exp\left(-\frac{t}{\tau}\right) \frac{dt}{\tau}$$

Assign temperatures with Burrows+ (1997) models and velocities according to Wielen (1977) disk heating model. Compute velocity dispersion as a function of spectral type (see Figure).

## 5. Implication for WFIRST:

For an isothermal disk, the vertical velocity dispersion is related to the vertical disk thickness of the disk:

$$z_{rel} \propto \frac{\sigma^2}{\Sigma}$$

The deviation in Fig 1 gives a change in scale heights of ~50 pc. The 2000 deg<sup>2</sup> of HLS should sample 10,000s of brown dwarfs on the kiloparsec scale, which gives an expected scale height uncertainty of ~5 pc for spectral type bins of ~2-3 subtypes (such as L0-L2 dwarfs). Therefore the HLS will provide key resolution on the issue of atmospheric cooling vs. Galactic scattering

## 4. Velocity Dispersions

Vertical velocity dispersions as a function of spectral type. The data points come from a host of published sources. The solid lines show two of our models: **red** (where we allow dwarfs to cool like Burrows+ 1997) and **blue** (where we hold the temperatures/types fixed to value at 1 Myr — non cooling model). The deviation at ~T0 is the thought experiment result (Ryan+ 2017, ApJ, accepted).

