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

R. E. Ryan, P. A. Thorman, S. J. Schmidt, S. H. Cohen, N. P. Hathi, B. W. Holwerda, J. I. Lunine, N. Pirzkal, R. A. Windhorst, & E. Young

SPACE TELESCOPE SCIENCE INSTITUTE

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:

$$\phi(m;\alpha)\,\mathrm{d}m \propto m^{-\alpha}\,\mathrm{d}m,$$
$$\psi(t;\beta,\tau)\,\mathrm{d}t \propto \left(\frac{t}{\tau}\right)^{\beta} \exp\left(-\frac{t}{\tau}\right)\,\frac{\mathrm{d}t}{\tau}$$

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:

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

The deviation in Fig 1 gives a change in scale heights of ~50 pc. The 2000 deg^2 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).