Statement of Research Interests

My previous research centered on the study of the mass distribution of brown dwarfs in young clusters, the field, and as companions. The goals were two-fold: 1) Test how well current brown dwarf evolutionary models can reconstruct the available data. 2) Determine how well the current data can constrain model mass distributions. To accomplish this I collected data from the literature on brown dwarfs in many environments and constructed synthetic distributions for comparison to those data. I utilized a flexible Bayesian statistical algorithm to achieve the comparison. Below, I outline the results of these endeavors, as well as current and future work that address the questions highlighted by my thesis project.

The Brown Dwarf Mass Function from Young Clusters to Companions

The overall mass distribution of stars, or their Initial Mass Function (IMF), the number of stars born per unit mass per unit volume, has long been known to reflect the processes by which they form. Beginning with Salpeter (1955) through today (Chabrier 2003) the quest for the IMF of stars, and now brown dwarfs, continues. However, study of brown dwarf masses is complicated. Brown dwarfs evolve quickly, unlike main sequence stars, which remain relatively unchanged for billions of years. If the luminosity of a main sequence star is known, the mass is known. Two brown dwarfs of the same luminosity may have very different masses because brown dwarfs do not maintain stable fusion processes. Without this energy supply, brown dwarfs cool and fade. This process is degenerate over age, mass, and luminosity, which results in brown dwarfs of different masses evolving through the same observable features.

Young Clusters

The reconstruction of brown dwarf mass functions of young clusters is relatively simple compared to analyzing the field because age is a known quantity. We compared several observed young cluster luminosity functions, the number of objects per unit magnitude per unit volume, to the model predictions. Overall, the agreement was good (Allen et al. 2003). We also identified a peak in the model luminosity functions that varies its location with age. This is the result of deuterium burning in brown dwarfs with masses between $\sim 0.013\ M_{\odot}$ and $\sim 0.075\ M_{\odot}$ (Burrows et al. 2001). This feature was seen at the detection limit of one cluster, IC 2391 (Barrado y Navascués et al. 2001). If confirmed, this transient feature could be used as an age diagnostic.

The Field

In Allen et al. (2005) I studied the brown dwarf mass function in the field. I developed a rigorous Bayesian statistical method for constraining model luminosity functions to those observed. I used a volume-complete sample of late-M and L dwarfs (Cruz et al. 2003,2005) and a sample of late-T dwarfs (Burgasser 2001) to constrain the models. These data were compared via the Bayesian algorithm to model luminosity functions derived from both power law and log normal forms, and were only weakly constrained. There were two main reasons for this: 1) Low intrinsic L dwarf space densities 2) Poor late-L and T dwarf statistics. The evolutionary models predict a limited mass range of main sequence L dwarfs, and that substellar Ls will evolve quickly. This leads to little sensitivity to variations in the mass function. The model luminosity functions show that late-L and T dwarfs are a much better gauge of the mass function than L dwarfs (Allen et al. 2005, Burgasser 2004), but these measurements are either highly incomplete or suffer from small number statistics. I concluded that the field IMF can only be weakly constrained. From this analysis, I have developed a method that indicates which data are needed to study the brown dwarf IMF.

Brown Dwarf Companions

The final portion of my thesis examined the companion distribution of brown dwarfs. Initial observations (Koerner et al. 1999, Reid et al. 2001, Burgasser et al. 2002, Close et al. 2002, Gizis et al. 2003, Bouy et al. 2003) indicate that the distribution of companions to brown dwarfs is different from higher mass stars (Duquennoy & Mayor 1991, Fischer & Marcy 1992). Brown dwarf binary systems appear to be skewed to near-equal mass pairs, whereas stellar binaries are drawn from a similar mass function as their primary. To test if this apparent difference was supported statistically, I applied the same Bayesian method used in the field mass function analysis to data from extent brown dwarf companion surveys. The results of this analysis indicate that the brown dwarf companion distribution is fundamentally different from that of higher mass stars (Figure 1).

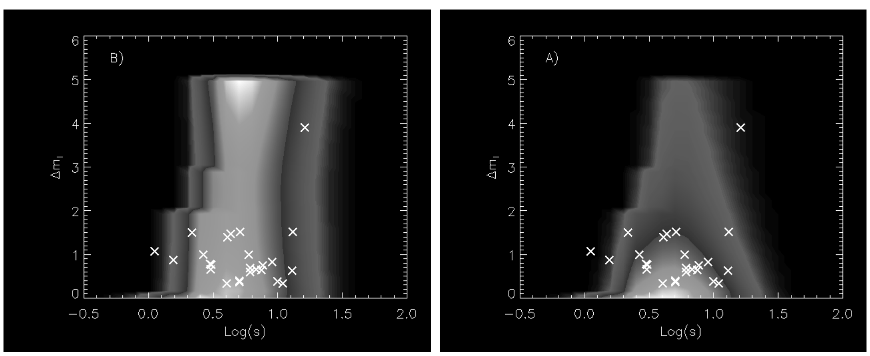

Fig. 1.— A) Multiplication of the observed window function with a companion distribution model drawn from a field IMF ($\alpha \sim -0.8$), where $\log(s)$ is the logarithm of the observed separation in AU, and Δm_I is the I-band magnitude difference between the companion and the primary. The grayscale is the probability of observing a companion at a particular point, where high probability is white and low is black. Note that this model predicts many more companions at large Δm_I's than were observed. B) The same as A), but with the best fit companion distribution model. The observed binaries from HST are displayed as X's, as summarized in Bouy et al. (2003).

Future Work

My future work will center on two outstanding issues from my thesis work: 1) The existence of the deuterium peak in the luminosity function of the young cluster IC 2391; 2) Obtain better constraints on the brown dwarf IMF. I will use a combination of ground- and space-based observations to carry out these goals.

IC 2391

I will apply for time on Spitzer to use its unique sensitive mid-infrared capabilities to detect and reliably classify low-mass members of IC 2391. In addition to these data, ground-based far-red optical and near-infrared data will be obtained. The combination of optical, near-infrared, and mid-infrared observations provide nearly complete sampling of each cluster candidate's spectral energy distribution. From this classification I can construct a rigorous sample and unequivocally determine if the deuterium peak exists in IC 2391. The existence of this peak can be used to test the underlying evolutionary models.

A Volume-Complete Sample of L/T Transition Dwarfs

As stated earlier, Allen et al. (2005) and Burgasser (2004) determined that late-L and T dwarf space densities act as brown dwarf mass function diagnostics, but currently lack the observations to accomplish that goal. The cross-correlation of the 2MASS and SDSS databases promise to provide very clean criteria to select candidate late-L and T dwarfs, especially the highly interesting L/T transition dwarfs. For 2MASS alone (Figure 2a), late-L and T dwarfs have colors and apparent magnitudes similar to those of distant giant stars (L dwarfs) and main sequence stars (L/T transition and T dwarfs). I can eliminate much of this contamination by using data from both 2MASS and SDSS. L and T dwarfs are very faint in the far-red optical compared to the near-infrared. This creates a sharp drop in flux from the range of wavelengths in 2MASS to that in SDSS, by which L and T dwarfs can be distinguished (Figure 2b).

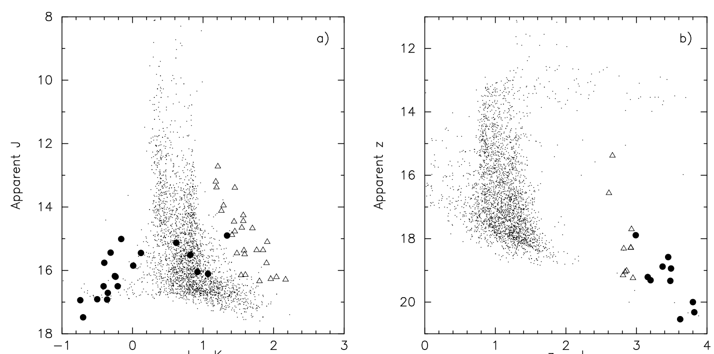

Fig. 2.— a) J vs $J - K$ color-magnitude diagram for a one degree field from 2MASS (small dots) and known L (triangles) and T (solid circles) dwarfs with trigonometric parallaxes (Knapp et al. 2004) shifted to 20 pc (absolute magnitude + 1.51). b) z vs $z - J$ color-magnitude diagram for the same field as a) using 2MASS objects with Sloan z-band photometry. The combination of these surveys provides for cleaner selection of L and T dwarfs.

Through collaborators in the SDSS brown dwarf group (Gillian Knapp, Dave Golimowski, Sandy Leggett, and others) I will apply for external member status in Sloan. This status is essential because the signals from L and T dwarfs in the SDSS data often lie below 5σ and are not included in the public database. I will carefully mine the SDSS data for these marginal detections. As part of the SDSS brown dwarf group I will have access to the expertise needed to extract sources from

SDSS and match them with 2MASS. In this way, I can construct a complete sample of late-L and T dwarfs. My thesis work on a flexible Bayesian statistical framework has uniquely prepared me to use these data to constrain the brown dwarf mass function.

Physical Properties

These samples of nearby L and T dwarfs and low-mass cluster brown dwarfs can be used to study this population's physical properties. The objects I find will be among the nearest known of their class, making it easier to obtain detailed observations. The high-quality spectra that can be obtained of these objects provide a wealth of information about their atmospheric chemistry and structure. In particular, the mechanisms behind the transition from L to T are likely dominated by changing atmospheric conditions, and more data are required to fully understand the physics behind the transition. During the next three to four years, Spitzer will provide crucial, mid-infrared coverage that will enable better understanding of the L/T transition. At the University of Arizona I will have institutional access to the ARIES and MMIRS instruments at the MMT. These instruments can provide detailed near-infrared spectra which, when joined with the Spitzer spectra, open a great window into the atmospheres of L/T transition objects. These data of a complete sample of L and T dwarfs and young cluster brown dwarfs can be used by the large brown dwarf group at UA to refine our understanding of these objects.

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