The Fundamental Importance of Brown Dwarf Binaries

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Outline

• Surveys for brown dwarf binaries
• Multiplicity properties of brown dwarfs
• Using binaries to measure fundamental parameters
Multiplicity has long been used as a constraint on the star formation process.

- Multiplicity fraction a signature of physical processes in stellar population
- What can the multiplicity properties of brown dwarfs tell us about their formation and evolution?

White et al. 1999
With the initial identification of brown dwarfs, multiple systems were quickly discovered.

- Discovery of CFHT-Pl-18 (1998), DENIS1228.2-1547B (imaging) and PPL 15 (spectroscopy) 1999

Martín et al. 1999

Basri et al. 1999
Imaging surveys with HST were the first to discover multiple systems in large numbers.

Ground based laser guide star adaptive optics is ideally suited for identifying low mass binaries.


Liu & Leggett 2005
Wide binaries have been effectively identified using all-sky, multi-epoch surveys.


Luhman 2013
Using analysis of spectroscopic “blends”, candidates binaries can be identified.

- Fits to low resolution spectra are better using “binary blended” template than single spectral type template
- RV monitoring after identification can reveal candidates are true binaries

2MASS 0320-0446, Burgasser et al. 2008
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2MASS 0320-0446, Blake et al. 2010
The number of radial velocity variables continue to increase.

- **Benefits from development of high precision RV monitoring in the near-IR**


Burgasser et al. 2012
Recent discoveries with microlensing have revealed binaries in a new region of parameter space.

- Closer separations can be probed (see talk tomorrow)

Choi et al. 2013
The binary frequency amongst very low mass objects has now been significantly probed.

- Burgasser et al. 2007 field binary fraction 10-30%
- Most systems tightly separated (a < 20 AU) and near equal-mass ratio
- Filling in the completeness gaps, this range continues to hold
  - Re-reductions, e.g. Pope et al. 2013
  - More spectroscopic binaries, e.g Blake et al. 2010
  - Additional wide systems, e.g. Faherty et al. 2011
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Multiplicity tends to be consistent between young objects and field objects, with a more “oddballs” found in separation and mass ratio.

- Binary fraction about the same (~20%), but tend to be wider separation systems with lower mass ratios (e.g., Martín et al. 2003)
- Are these differences resulting from incorrectly modeled masses or from incompleteness of field surveys?

Duchêne et al. 2013 (submitted)
The declining multiplicity fraction as a function of stellar mass is a significant test of star formation theories.

- Fraction declines from nearly 100% at the highest masses to ~20% for VLM objects.
- Multiplicity in 1-10 AU range fairly consistent up to 1.5 $M_\odot$ in the field (Duchêne & Kraus 2013).
- Evolution with time likely a function of dynamical processes.

Raghavan et al. 2010
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Duchêne & Kraus 2013
Binaries are excellent resources for the measurement of fundamental parameters.

- Empirical measurements of fundamental parameters are essential for feedback into brown dwarf models
  - Measured parameters like metallicity, age, mass, radius, temperature, and rotation can help constrain brown dwarf physics by comparison to atmosphere and evolutionary models
  - Binaries offer the best (and sometimes only) means of achieving these empirical measurements
Brown dwarfs that are companions to higher mass stars can yield parameters like metallicity and age.

- Metallicity and age often easier to measure for higher mass objects
- A number of low mass companions to higher mass stars have been identified (e.g., Burgasser et al. 2005, Luhman et al. 2007, 2012, Day-Jones et al. 2011, Deacon et al. 2012, Gomes et al. 2013)

Burningham et al. 2009
Binaries near the L/T transition offer excellent peak into the atmospheric properties of this region.

- Coeval binaries showed that J band “bumps” were real features (e.g., Burgasser et al. 2006, Liu et al. 2006, Stumpf et al. 2010, Dupuy & Liu 2012)

Looper et al. 2008
There are now quite a few empirical mass estimates for brown dwarfs.

- Orbital monitoring programs began with the discovery of binary brown dwarfs (e.g., Basri et al. 1999, Lane et al. 2001)
- With continued discovery of new spectroscopic binaries, more masses will be obtained!
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Orbits not only give you masses, but other orbital parameters that can constrain bulk population properties.

- Ex., eccentricity distribution compared to higher mass binaries can yield useful information about the formation similarities and differences.

Distribution from Dupuy & Liu 2011 as reproduced by Duchène & Kraus 2013
Rotational properties of binaries can possibly hint at dynamical history.

- Brown dwarfs known rapid rotators from studies of single objects (e.g., Reiners & Basri 2008)
- Different $v\sin i$ measured for some brown dwarf binaries

Konopacky et al. 2012
Rotational properties of binaries can possibly hint at dynamical history.
Ultimately we need more empirical measurements of radius and temperature – more eclipsing binaries!

- Temperature estimates for visual binaries end up model-dependent
- Wealth of information from 2MASS J0535-05AB in terms of comparisons to models is example of necessity

Stassun et al. 2012
Summary

• Brown dwarfs in binary systems have been incredibly important for advancing our understanding of these objects
• Active field with lots of exciting new results all the time!!
  – At this conference alone, 20 presentations!