Binary Stars and Time-Domain Astronomy with WFIRST-AFTA

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On behalf of Marc Pinsonneault

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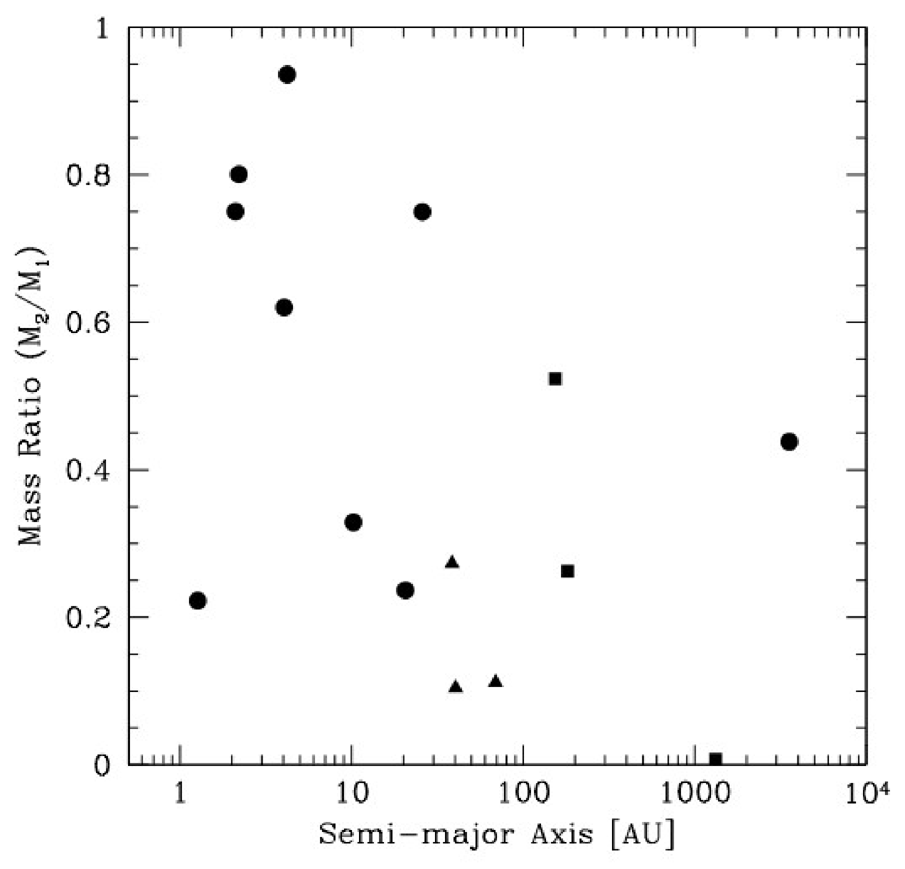
Low mass binaries

- Low mass stars and L, T brown dwarfs
- Multiple possible formation mechanisms (core accretion, gravitational instability, fragmentation)



Multiplicity is one key to understanding formation mechanisms

→ Need distributions of binary separations, mass ratios, eccentricity

From hydrodynamic simulation of fragmentation process [Bate 2009]

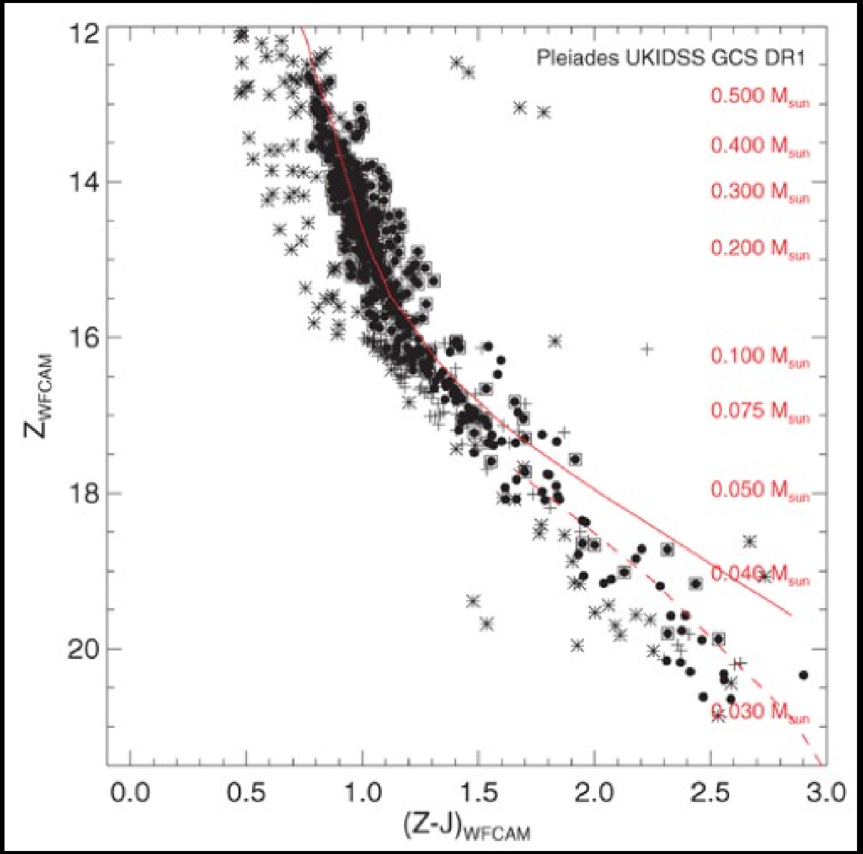
Probing the Shape of the IMF at low masses

- Deep, multi-epoch imaging of young star clusters and star forming regions

→ could detect brown dwarfs

down to planets $5M_{Jup}$ in 100Myr

old clusters or lower.



Lodieu et al. 2012

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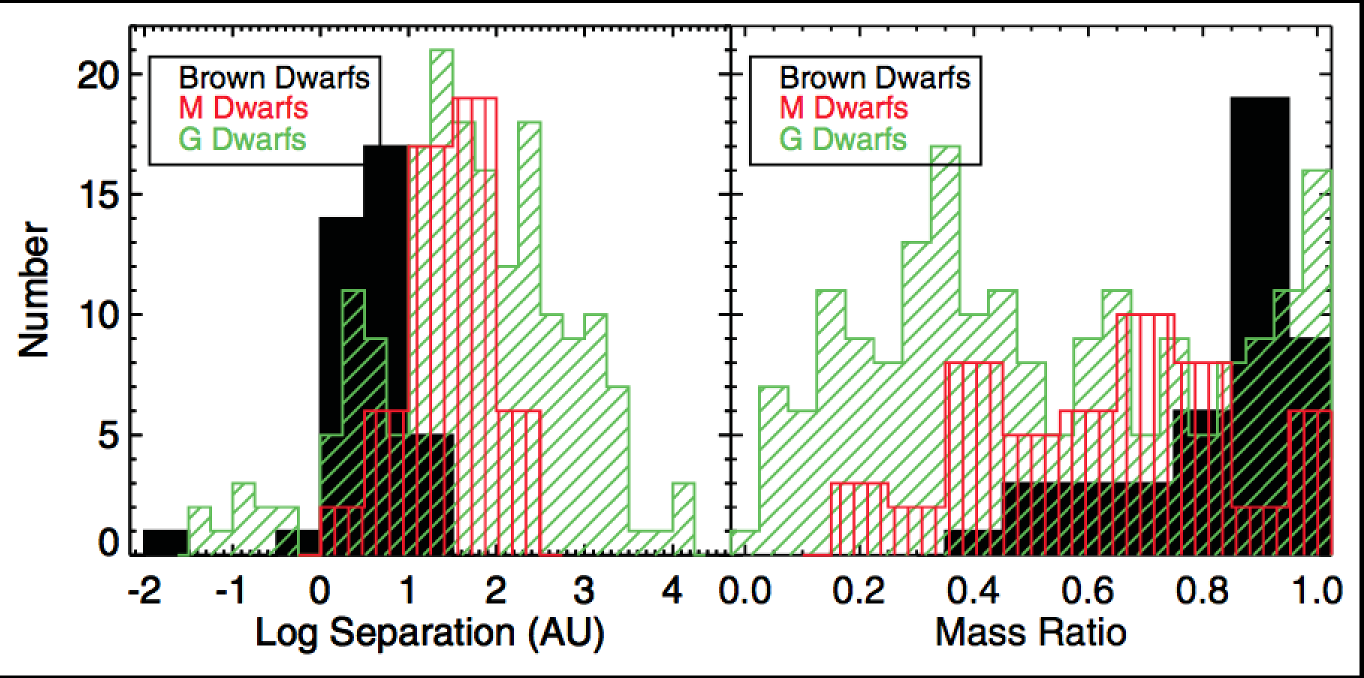
Probing the Shape of the IMF at low masses

High cadence survey data will provide astrometry, photometry
→ detect binaries via image, astrometric motion, eclipses

→ binarity fraction
→ orbital parameters
→ mass, radii



Comparing properties of brown dwarf and stellar binaries
Allers, 2012

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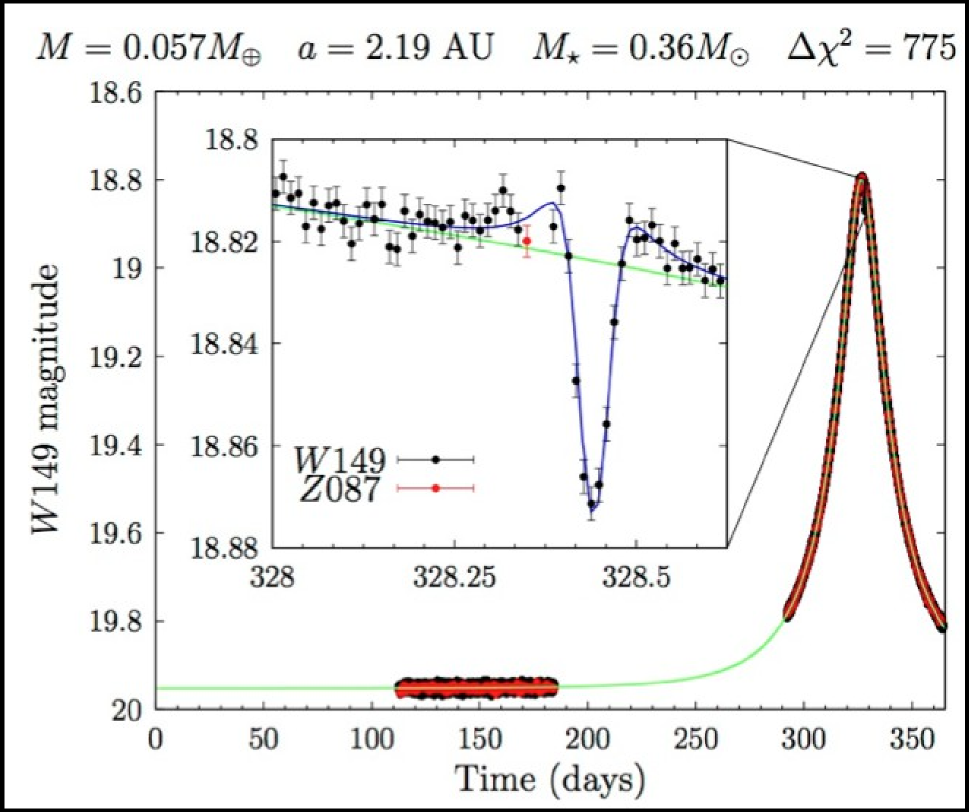
Binary Microlenses

Microlensing Survey will be sensitive to binaries of all mass ratios with orbital separations ~ 0.3—30 AU

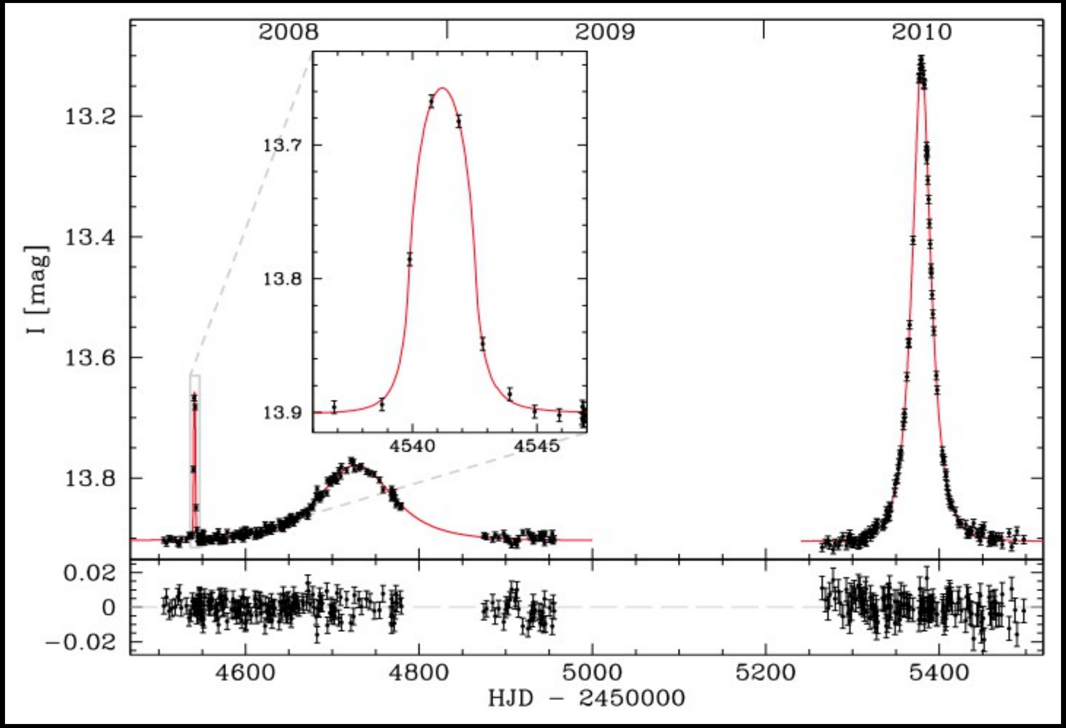
→ Comparison of binary populations in different region of the Galaxy

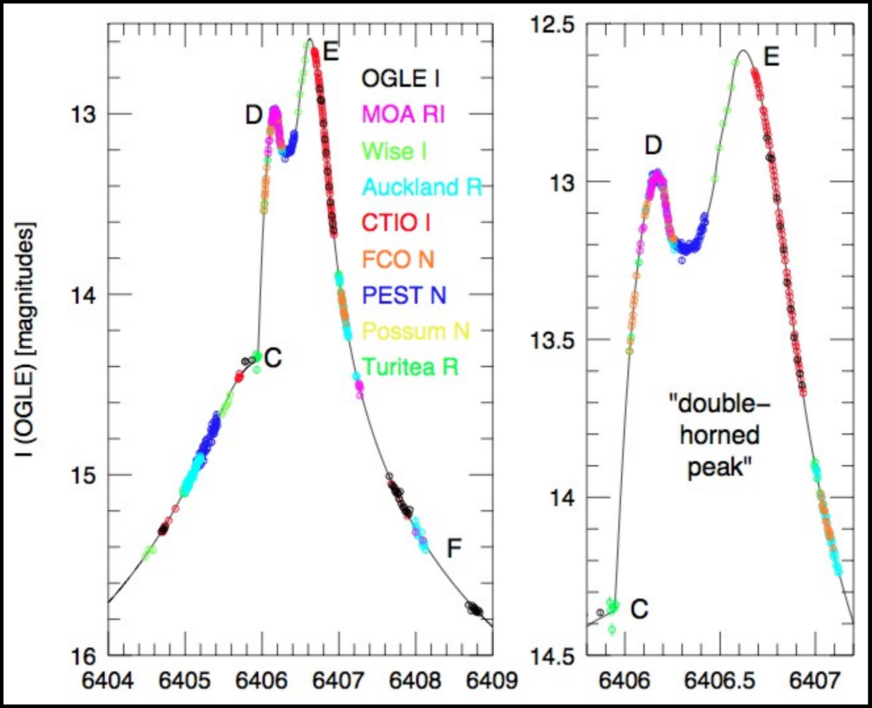
→ Sensitive to binarity even for extremely low-mass brown dwarf hosts



Planets in Binaries from Microlensing

OGLE-2008-BLG-0092
4MUranus planet orbiting 0.7MSol star at ~18AU with stellar (or BD) companion





OGLE-2013-BLG-0341
Terrestrial mass planet in binary

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Properties of Giants Stars

- CoRoT, Kepler have proven the value of asteroseismology in determining fundamental properties and physics of stars.
- Impacts on stellar evolutionary models, transiting planet models, etc.
- Red giants stars measured to date rather faint

  → additional constraints uncertain [Kallinger et al 2010]

- WFIRST astrometry will enable more precise mass measurements from astroseismology

Asteroseismology of Giant Stars

Asteroseismology measures mean density and surface density, from which we can derive R, M [Kallinger et al. 2010]:

$$\frac{\rho}{\rho_\odot} \simeq \left(\frac{\langle \Delta\nu_{nl}\rangle}{\langle \Delta\nu_{nl}\rangle_\odot}\right)^2;$$

$$\frac{g}{g_\odot} \simeq \frac{\nu_{\max}}{\nu_{\max,\odot}}\left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{1/2};$$

Where

$<v_{nl}>$ is the large-frequency separation

V_{max} is the maximum oscillation power

These can be combined to extract the stellar radius and mass:

$$\frac{R}{R_\odot} \simeq \frac{\nu_{\max}}{\nu_{\max,\odot}}\left(\frac{\langle \Delta\nu_{nl}\rangle}{\langle \Delta\nu_{nl}\rangle_\odot}\right)^{-2}\left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{1/2};$$

$$\frac{M}{M_\odot} \simeq \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right)^3\left(\frac{\langle \Delta\nu_{nl}\rangle}{\langle \Delta\nu_{nl}\rangle_\odot}\right)^{-4}\left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{3/2},$$

- Need to verify that these relations produce true mass measurements.
- Some eclipsing binaries have yielded radii and masses

Gould et al. 2014

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Asteroseismology + Parallaxes

Parallaxes from WFIRST will provide an independent check on the stellar radii derived from asteroseismology if the surface brightness can be estimated.

Independent masses can then be derived from:

$$\frac{M}{M_\odot} \simeq \left(\frac{\langle \nu_{nl} \rangle}{\langle \nu_{nl} \rangle_\odot}\right)^2 \left(\frac{R}{R_\odot}\right)^3$$

If S/N is high

$$\frac{M}{M_\odot} \simeq \frac{\nu_{\rm max}}{\nu_{\rm max,\odot}} \left(\frac{T_{\rm eff}}{T_{\rm eff,\odot}}\right)^{1/2} \left(\frac{R}{R_\odot}\right)^2$$

For lower S/N

→ Combining these measurements with the HR diagram, we can extract
  * information about chemical evolution (helium)
  * binaries: merger products with unusual masses in the post-MS
  (otherwise difficult to detect in standard HR diagrams.)

Summary

- Distributions of low-mass binary parameters will give clues to formation scenarios
- WFIRST will build statistically significant samples through deep imaging, microlensing
- Sensitive to planets in binary systems

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