



Companions to White Dwarfs

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Outline

- ▶ Why study white dwarf companions?
- ▶ Previous imaging surveys
- ▶ The Robo-AO survey

Formation and Evolution

- ▶ MS → RGB → AGB
- ▶ Large envelope may engulf companion
- ▶ Depending on initial orbital separation and mass:
 - ▶ Ablated and destroyed
 - ▶ Gain mass and shrink orbit (Livio, 1984)
 - ▶ $\sim 0.02 M_{\text{sun}}$, ~ 5 AU
 - ▶ No mass change and expand orbit (Jeans, 1924)
- ▶ Critical orbit ~ 5 -10 AU (Soker 1994)
 - ▶ Bimodal distribution

Why target WDs?

- ▶ **Common envelope evolution**
 - ▶ Mass transfer
 - ▶ Orbital changes
 - ▶ Critical for PN, CVs, Xray Binaries

- ▶ **High mass MS binary fraction**
 - ▶ Upto 10^4 times fainter, blue peaked
 - ▶ High rotation → RV searches difficult
 - ▶ Star formation models

Why target WDs?

- ▶ **Constraints on planetary/companion evolution**
 - ▶ Get ages from MS + WD cooling age
 - ▶ Model free estimates of mass & luminosity
 - ▶ Used to test evolutionary models (Pinfield et al, 2006)

- ▶ **Discovery of dusty disks around ~8 WDs**
 - ▶ Suggests survival of terrestrial planets through RGB

How do we look for these?

- ▶ **Photometric surveys**

- ▶ Look for IR excess (Maxted 2009, Green 2000)
- ▶ No RV/orbital information

- ▶ **RV surveys**

- ▶ Measure spectral shifts (Schultz 1996)
- ▶ Time intensive, fewer targets
- ▶ Hard to find low mass companions

- ▶ **Imaging surveys**

- ▶ Need high resolution (Farihi, 2011)
- ▶ Need followup to get spectral type, temperature
- ▶ Get orbital distributions

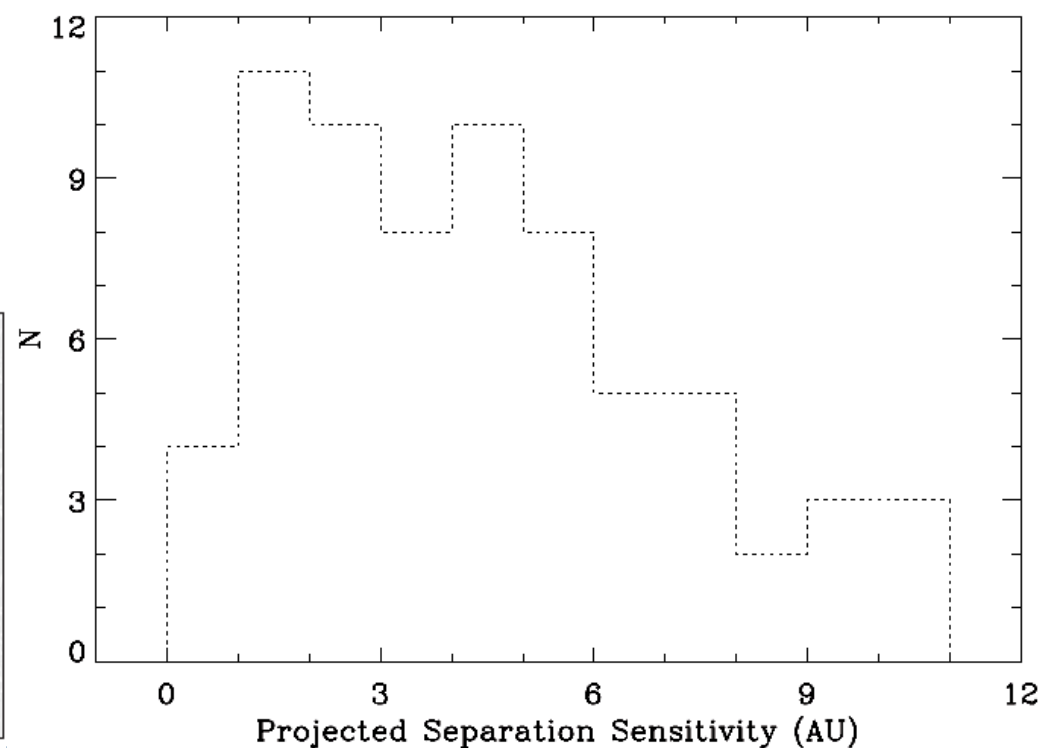
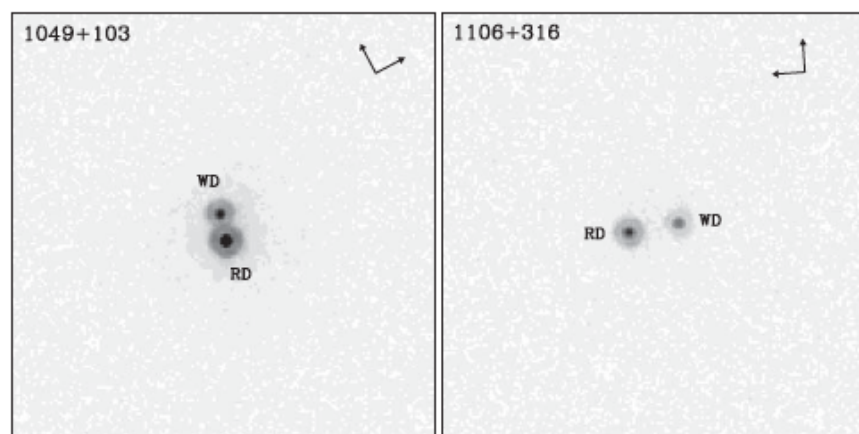
Recent Imaging Searches

| Survey | Targets | Sample Size | Limit (M_{Jup}) | Separation (AU) | Binary Fraction |
|-------------------|--------------------|-------------|----------------------------|-------------------------------------|--|
| McCarthy (2004) | G K M | 102 178 | > 12 > 30 5 – 10 | 75 – 3000 140 – 1200 75 – 300 | $1 \pm 1\%$ $0.7 \pm 0.7\%$ < 3% |
| Farihi (2005) | WD | 261 86 | > 52 > 51 | 100 – 5000 50 – 1100 | < 0.5% < 0.5% |
| Allen (2007) | M7 – L8 | 132 | > 52 | 40 – 1000 | < 2.3% |
| Lafrenière (2007) | F G K M | 85 | 13 – 40 | 25 – 250 | < 5.6% |
| Nielsen (2008) | A F G K M | 60 | > 4 | 20 – 100 | < 20% |
| Robo – AO (2011) | A – late M + WD | ~ 3000 | ~ 100 | 5 - 1000 | |

Table data from Hogan et al (2009)

HST Survey (Farihi, 2010)

- ▶ 72 WD – RD systems (pre-selected)
- ▶ Studied with HST imaging: 0.074" @F814W
- ▶ Consistent with a bimodal distribution



DODO Survey (Hogan '09)

- ▶ 23 WDs surveyed with Gemini
- ▶ Sensitive to $T < 500$ K (Spectral type $>T8.5$)
- ▶ Ranges between 60 – 200 AU
- ▶ Tentative result: No companions found.
 - ▶ Calculated limit: $< 5\%$ WDs have companions

Robo-AO Survey: Goals

- ▶ **Raw binarity fraction**
 - ▶ Over a large mass range
 - ▶ Effect of mass loss on binarity
- ▶ **Effect of common envelope evolution**
 - ▶ On mass and orbit of companions
- ▶ **Population of brown dwarf companions**

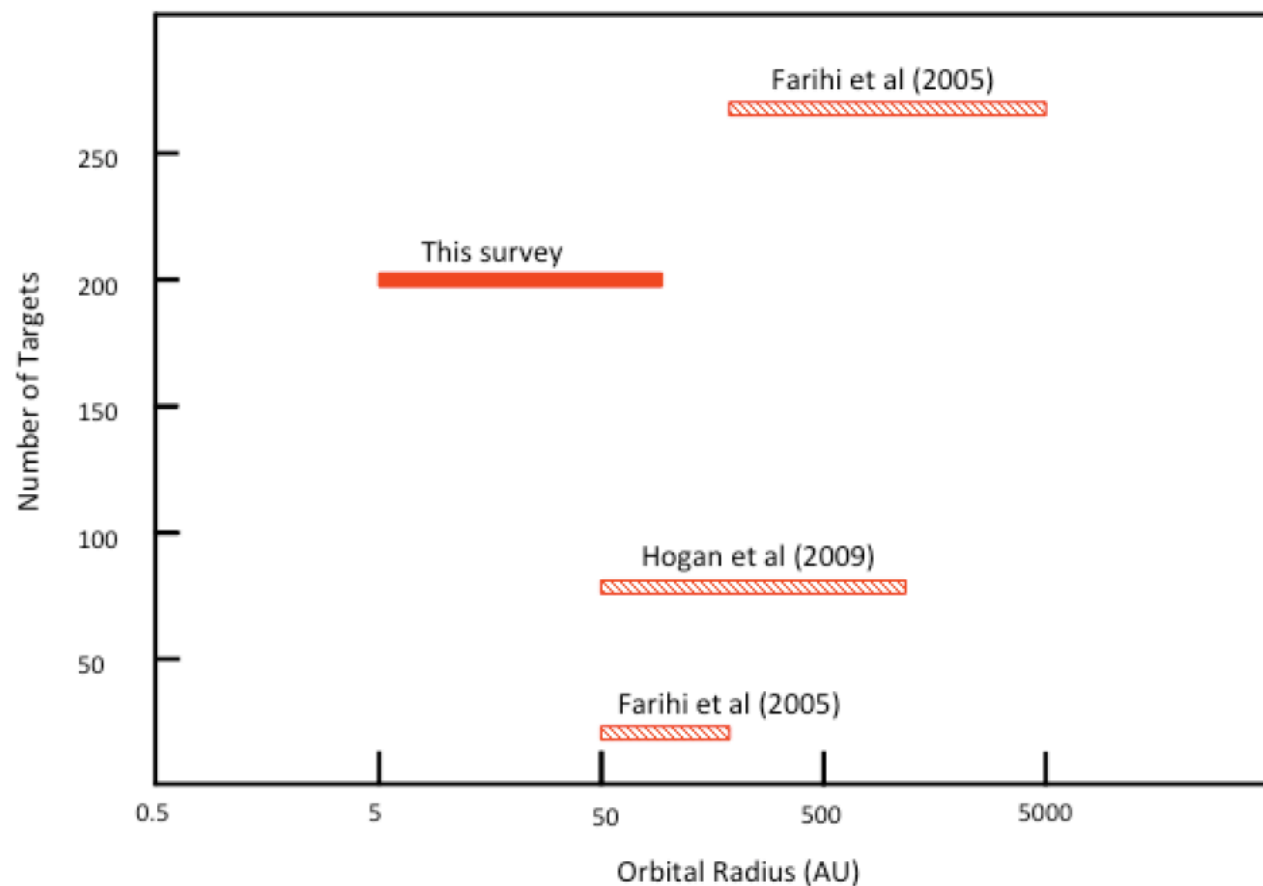
Sample Selection Biases

- ▶ **Colour selection**
 - ▶ IR, optical colours affected by companion
 - ▶ Selects against binaries
 - ▶ UV colours are pure, but influence mass (Green, 2000)
 - ▶ Lower mass \rightarrow larger WD \rightarrow brighter at same T
 - ▶ High interstellar extinction \rightarrow brighter are selected
 - ▶ Changes mass dependence of binary fraction

Robo-AO Survey I

- ▶ **DENSE Survey of WDs**
 - ▶ ~ 200 WDs
 - ▶ Volume limited sample (~40 pc)
 - ▶ Not biased by colour/spectral selection
- ▶ H band and i band observations
- ▶ Compare to DSS to understand CPM
- ▶ Can detect:
 - ▶ Good contrast in IR
 - ▶ Brown dwarfs at ~0.5'' separations

Robo-AO Survey II



Comparison with other WD imaging surveys

Summary

- ▶ Proposed survey of WD companions
- ▶ Scan volume limited sample of 200 WDs
- ▶ Raw binary fraction to $\sim 1\%$
- ▶ Can detect brown dwarf companions