GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

The DODO Survey: Imaging Planets Around White Dwarfs

Emma Hogan, Gemini Observatory

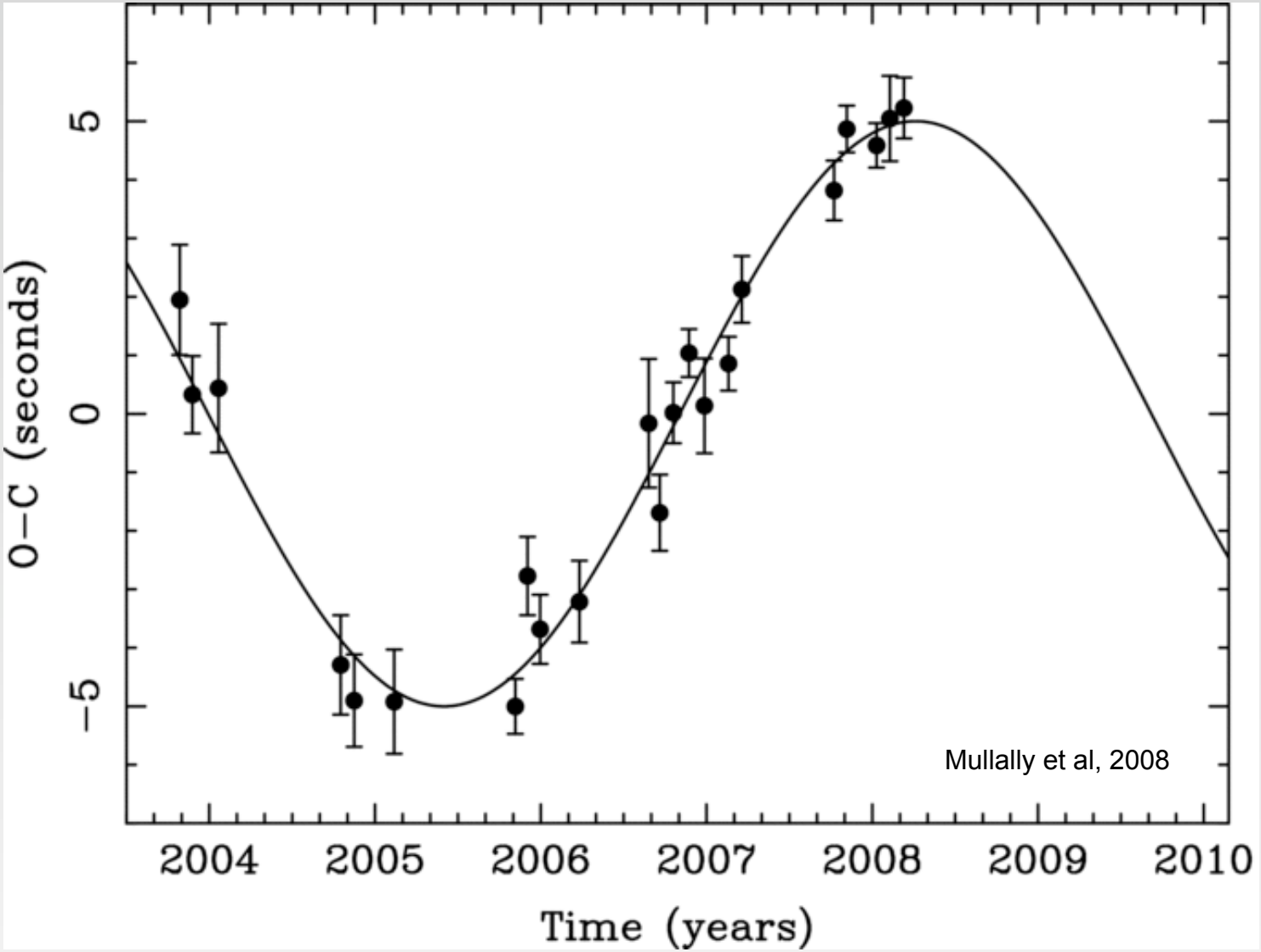
Matt Burleigh, University of Leicester

Fraser Clarke, University of Oxford

[Hogan et al, 2009, MNRAS, 396, 2074]

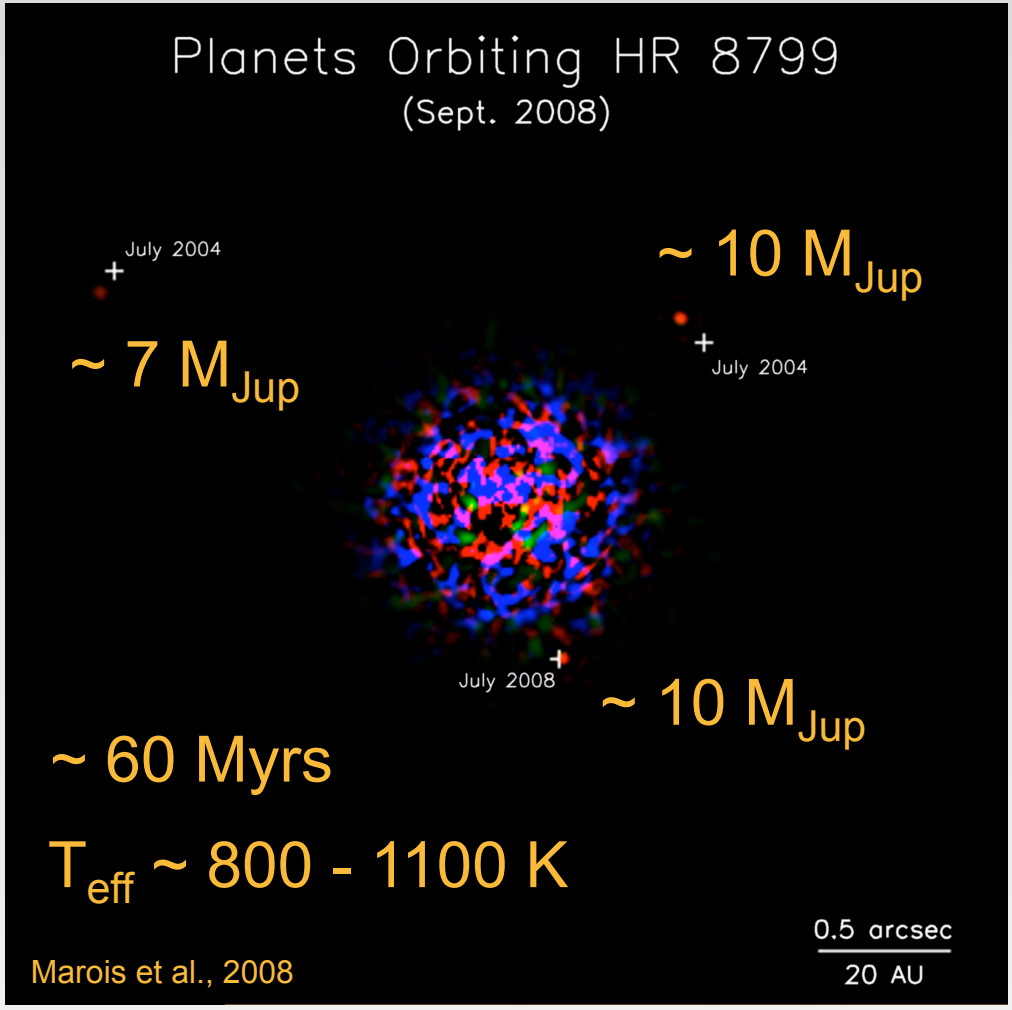
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

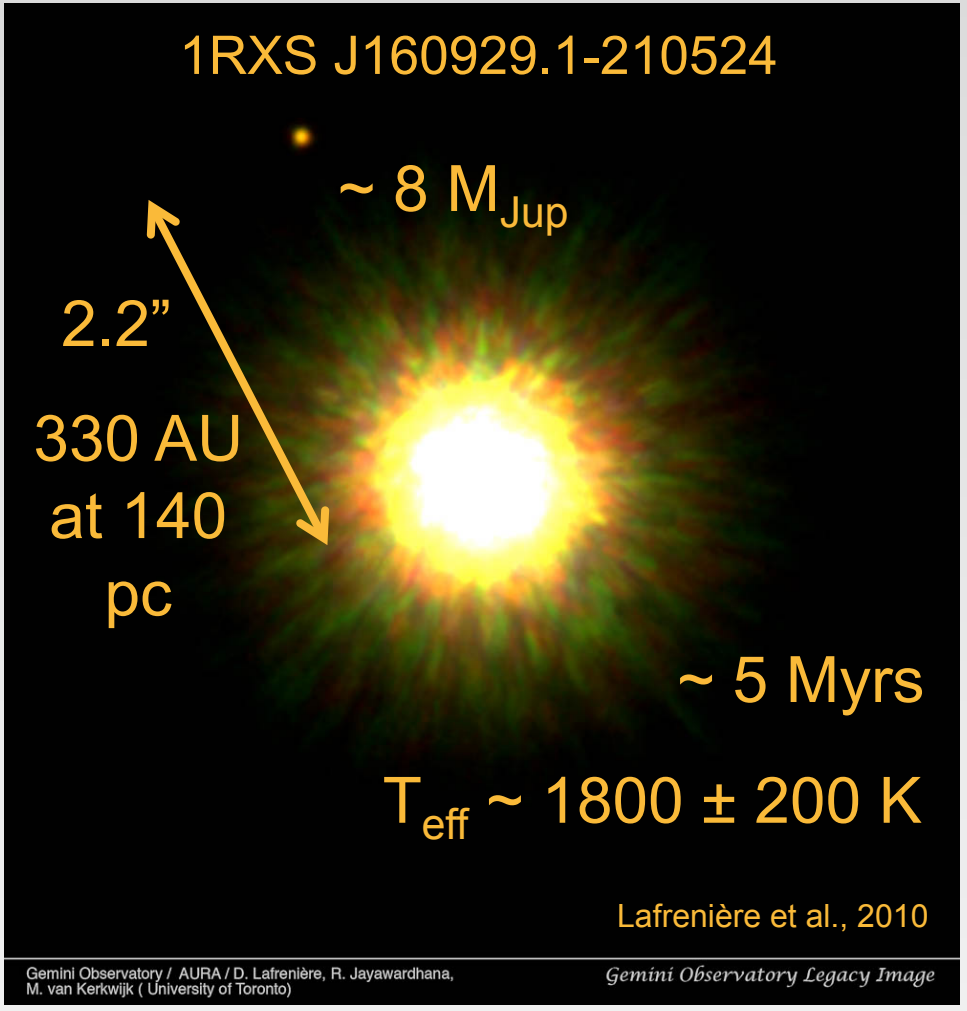
Planets around WDs?



GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

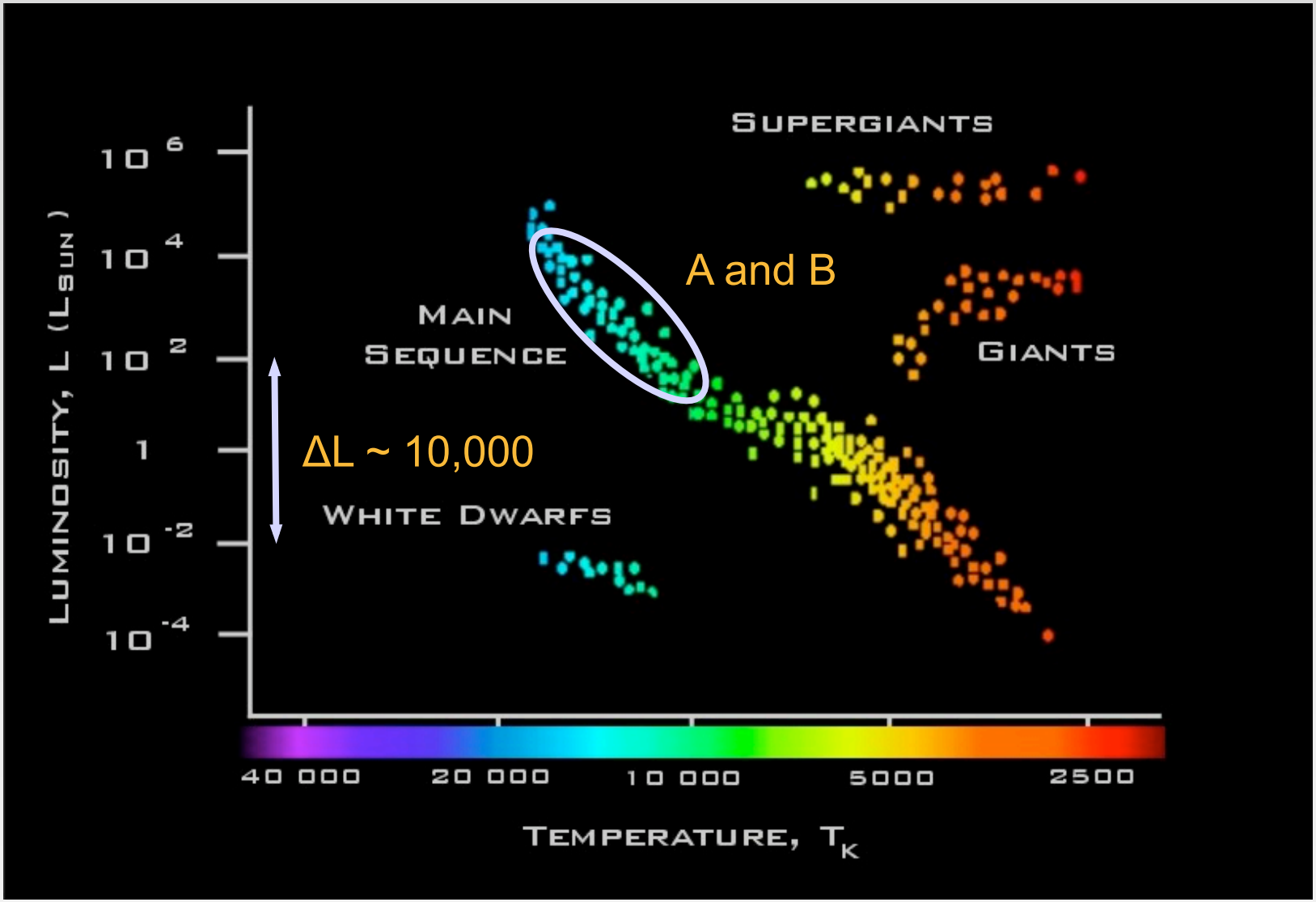
Imaging Planets





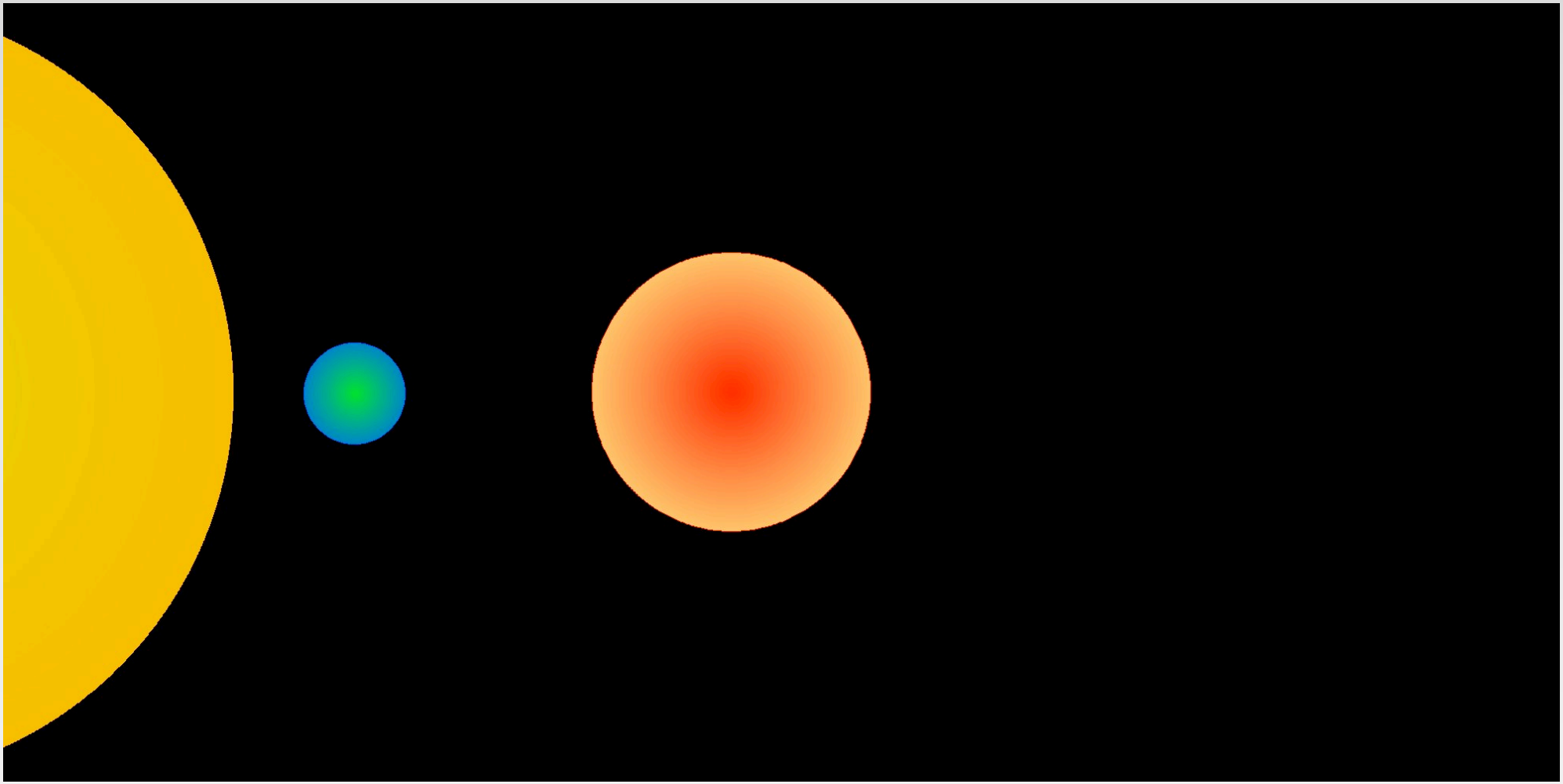
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Reason 1: Contrast



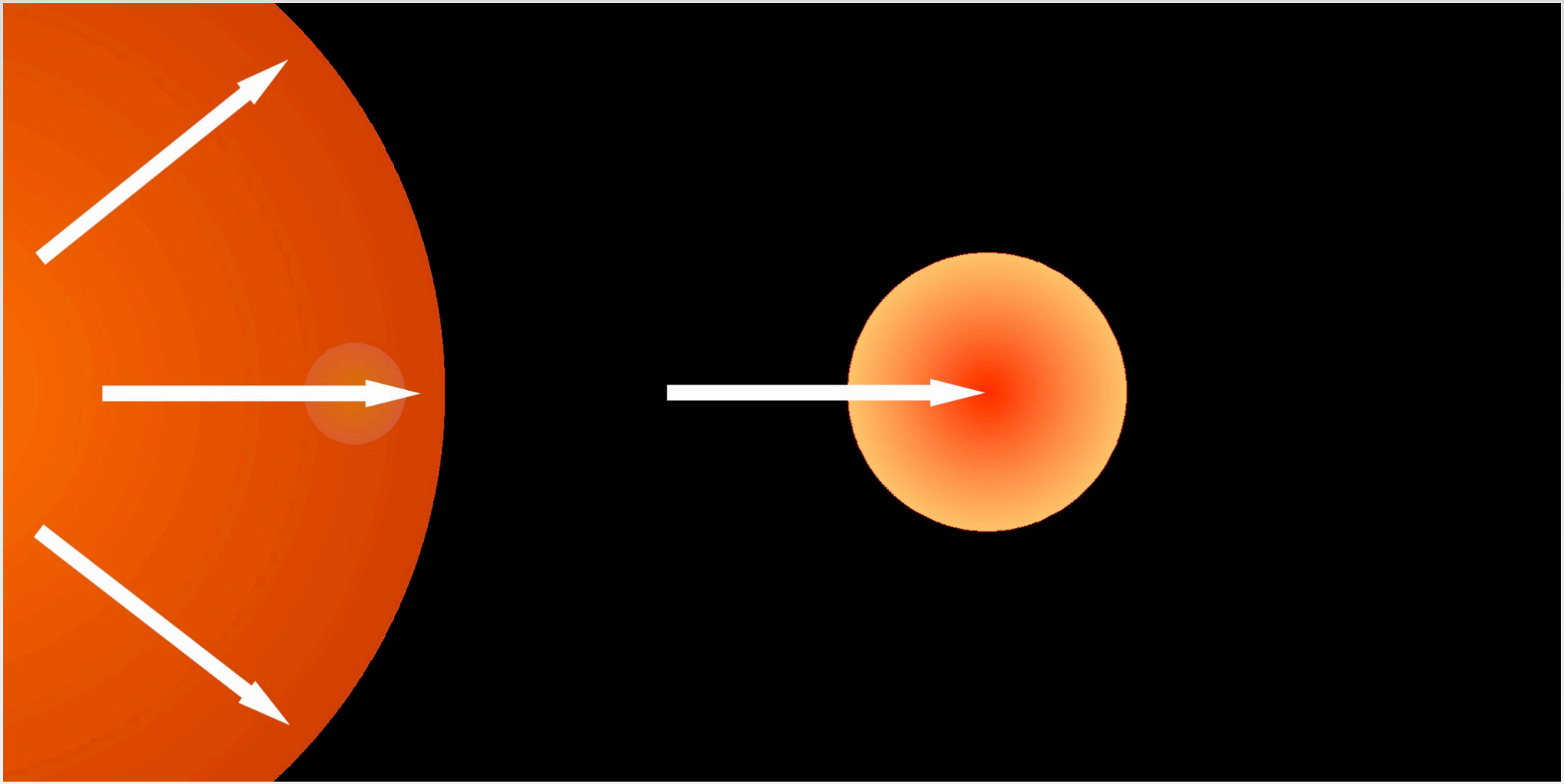
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Reason 2: Resolution



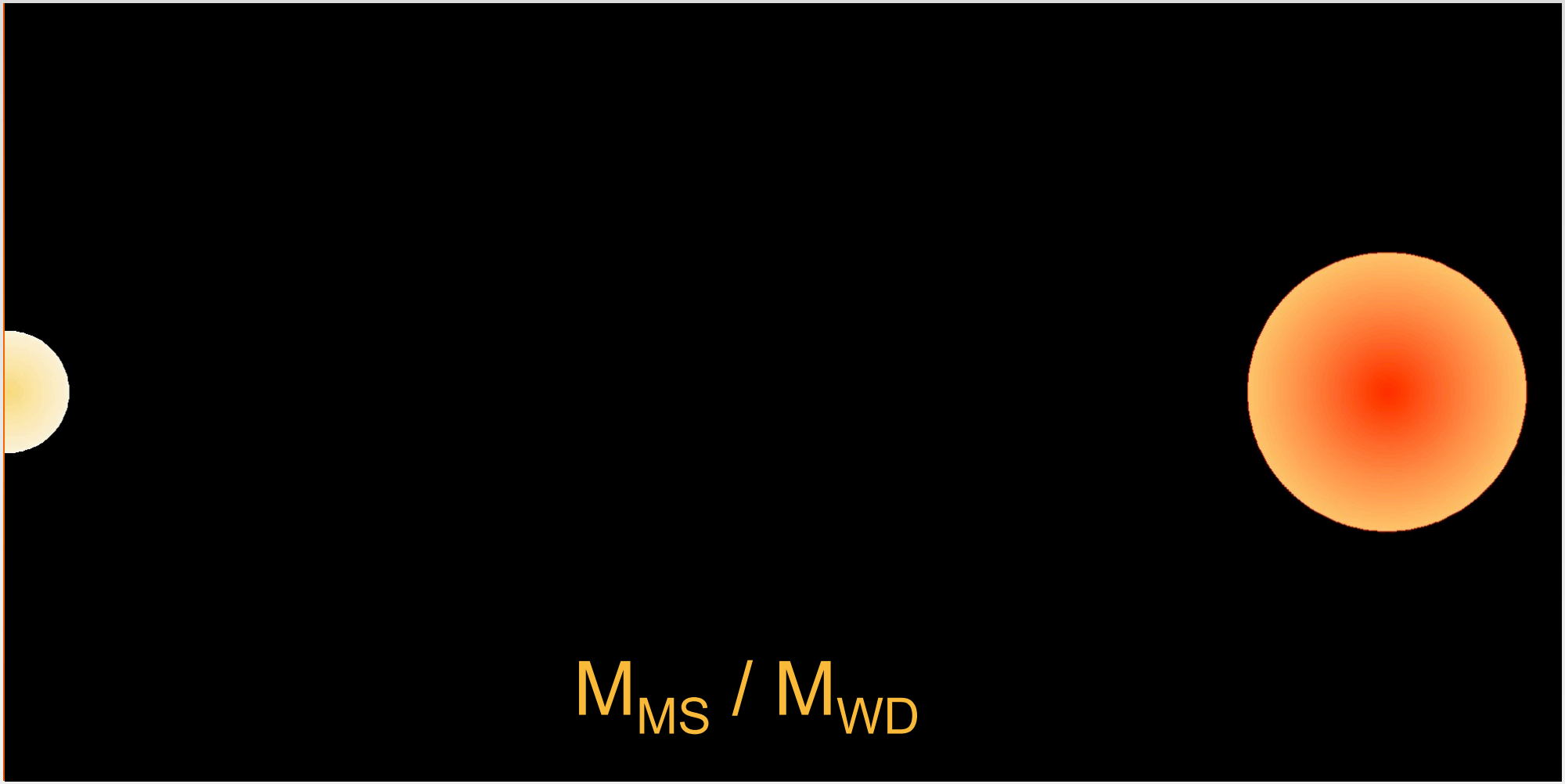
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Reason 2: Resolution



GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Reason 2: Resolution



GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Why Planets Around WDs?

- Spectroscopy of cool, low mass objects
- Constraints on evolutionary models
- Age of system can be determined without the use of models:
  - white dwarf cooling age
  - mass and lifetime of main sequence progenitor
- Provides model-free benchmark estimates of planetary masses

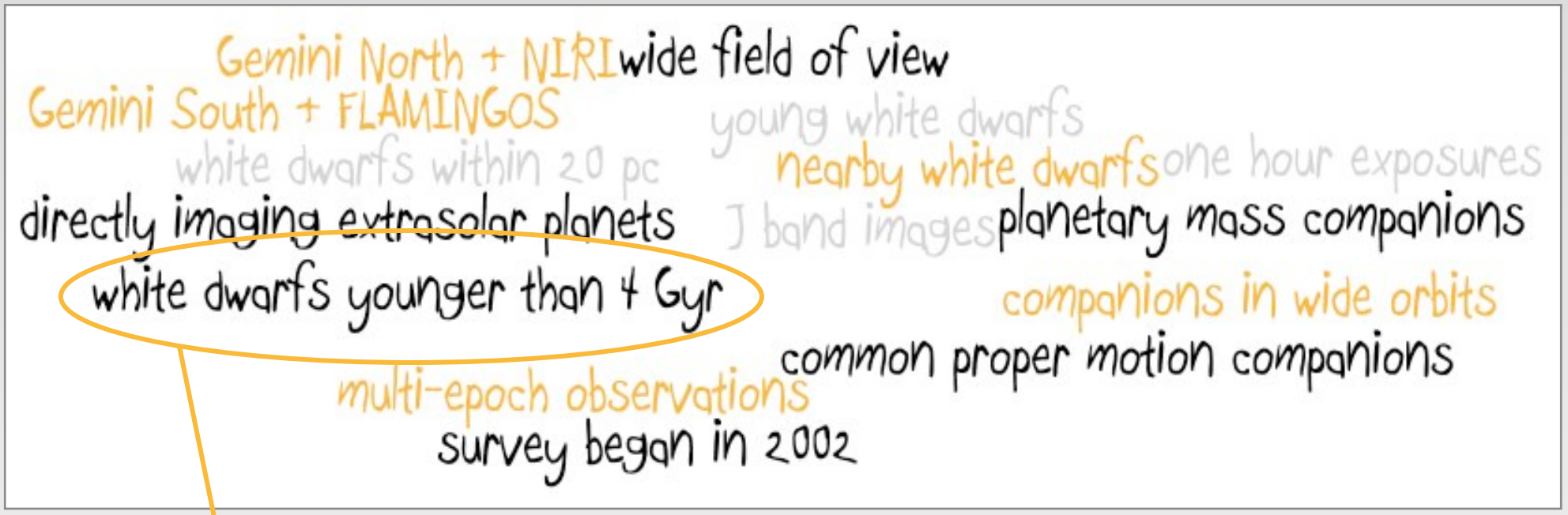
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

DODO?

Degenerate Objects around Degenerate Objects

Emma Hogan, 17th European White Dwarf Workshop, August 16-20, 2010

The DODO Survey



wordle from http://www.wordle.net/

Total age = main sequence lifetime + white dwarf cooling age

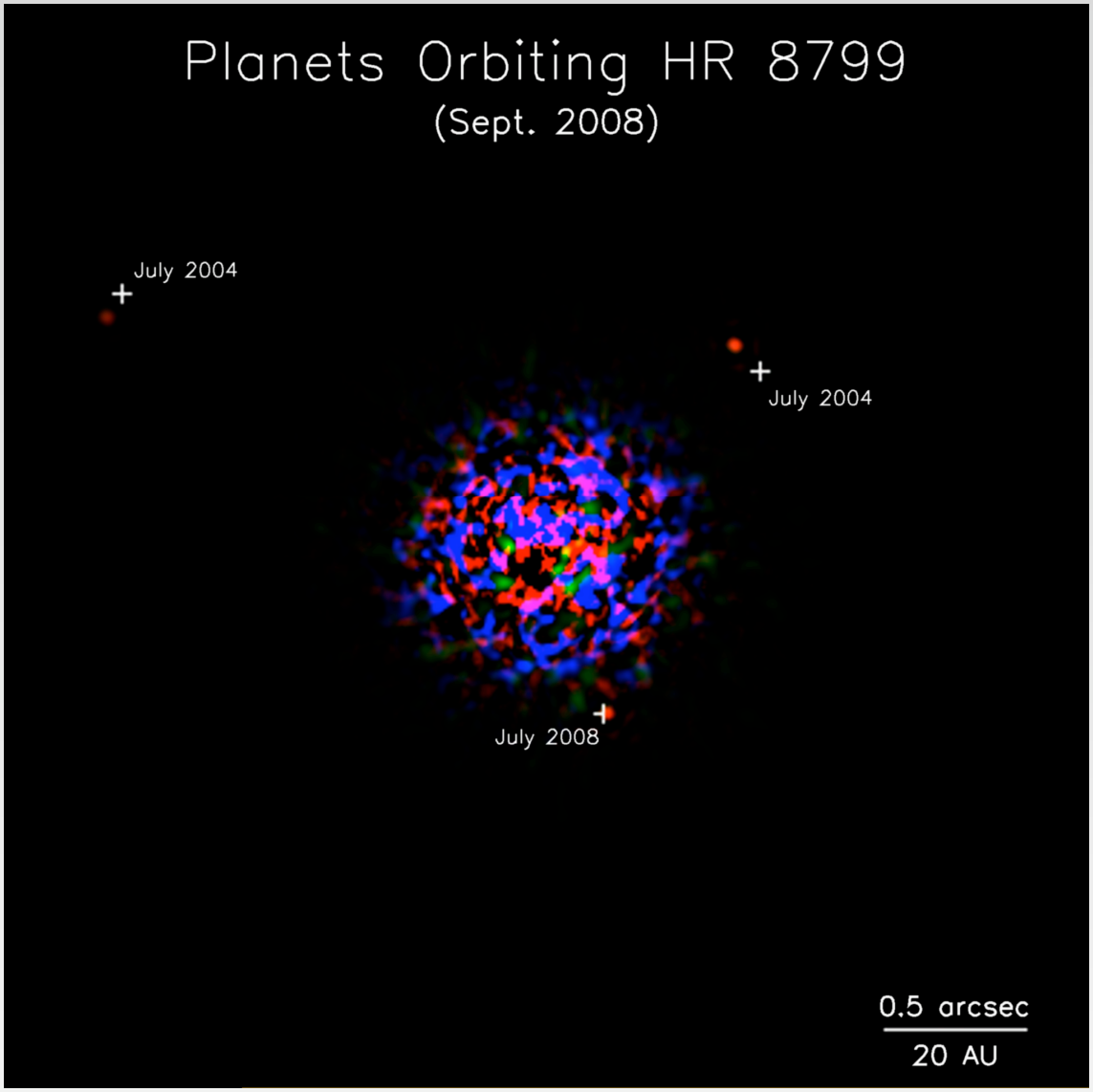
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Models

- IFMR (Dobbie et al., 2006):
  - $M_{WD} = 0.133\ M_{MS} + 0.289$
- Main sequence lifetime (Wood, 1992):
  - $t_{MS} = 10\ (M_{MS} / M_{\odot})^{-2.5}$ Gyrs
- White dwarf cooling age (Fontaine et al., 2001)
- 'COND' evolutionary models for cool brown dwarfs and extrasolar planets (Baraffe et al., 2003)

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Imaging Planets



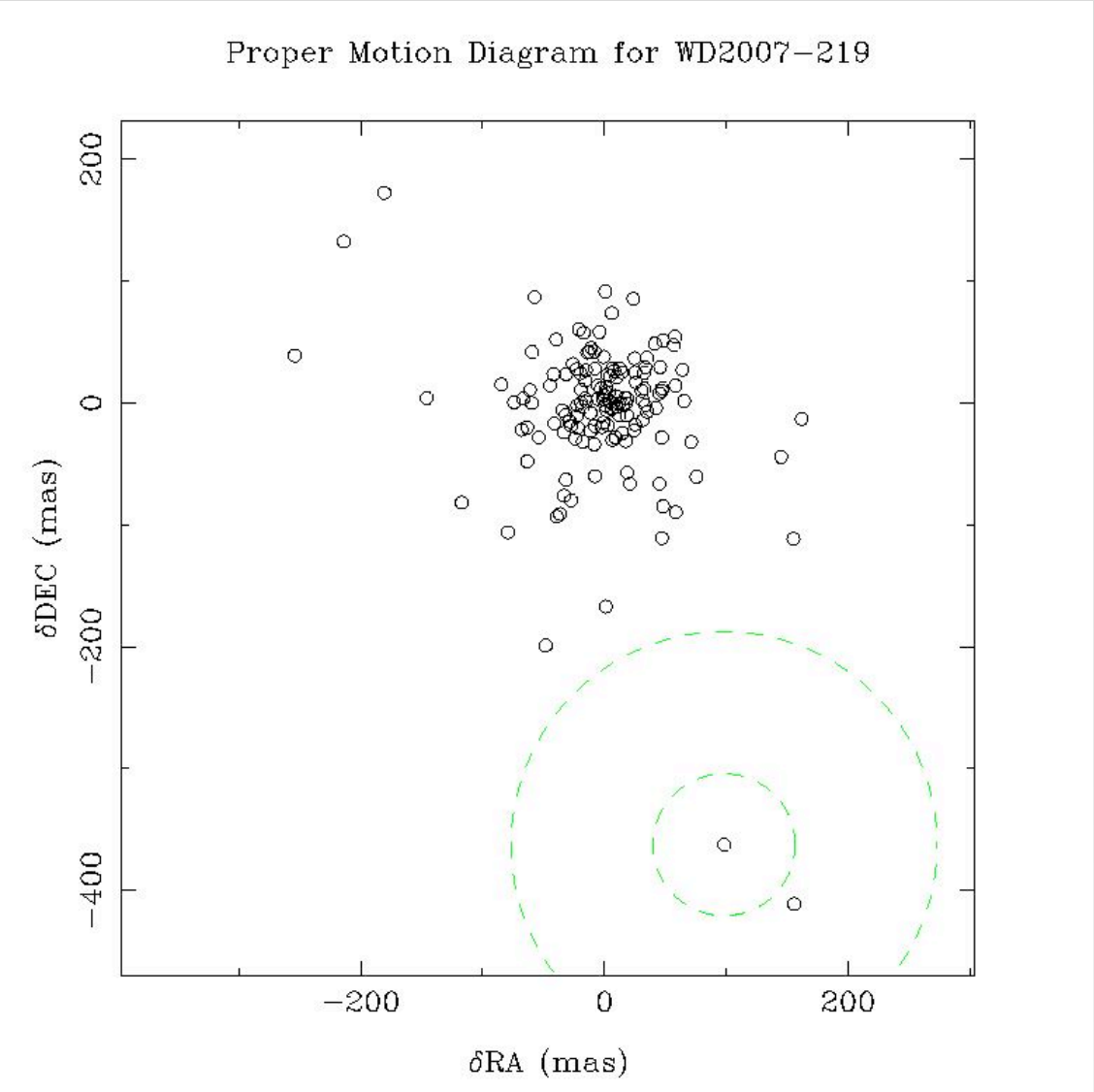
- $M_{MS} \sim 1.5\ M_{\odot}$
- $M_{WD} = 0.133\ M_{MS} + 0.289$

  → $\sim 0.49\ M_{\odot}$
- $M_{MS} / M_{WD} \sim 3$
- 24 AU → 74 AU
- 38 AU → 117 AU
- 68 AU → 209 AU
- HR8799 is 39.4 pc away

  → ~ 1.9 - 5.3”

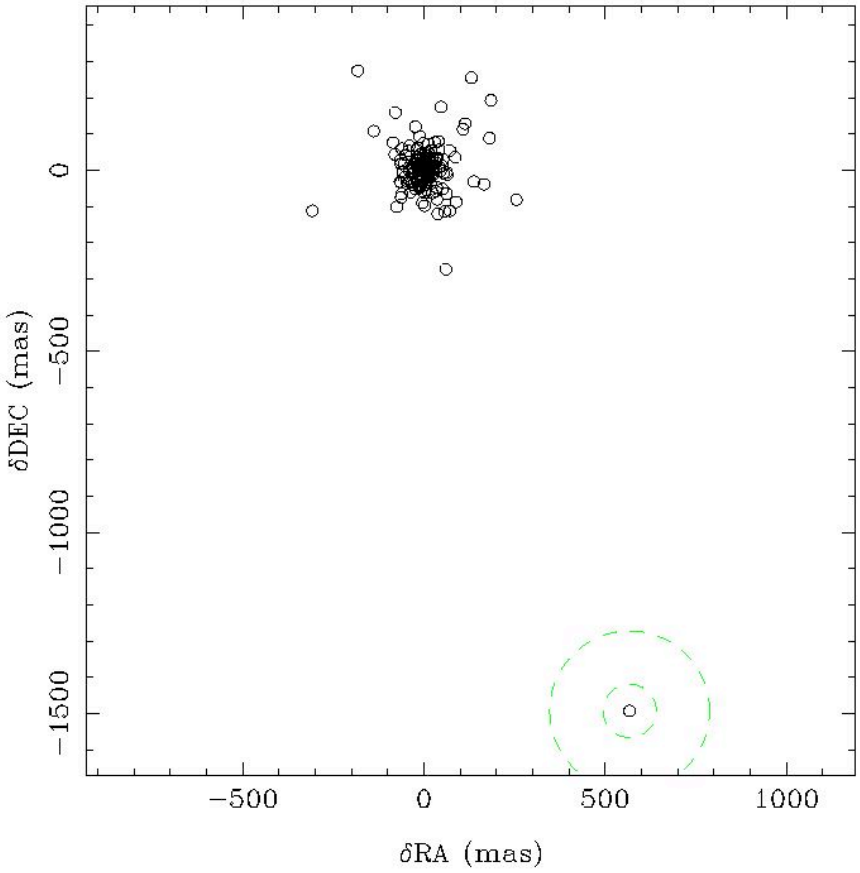
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

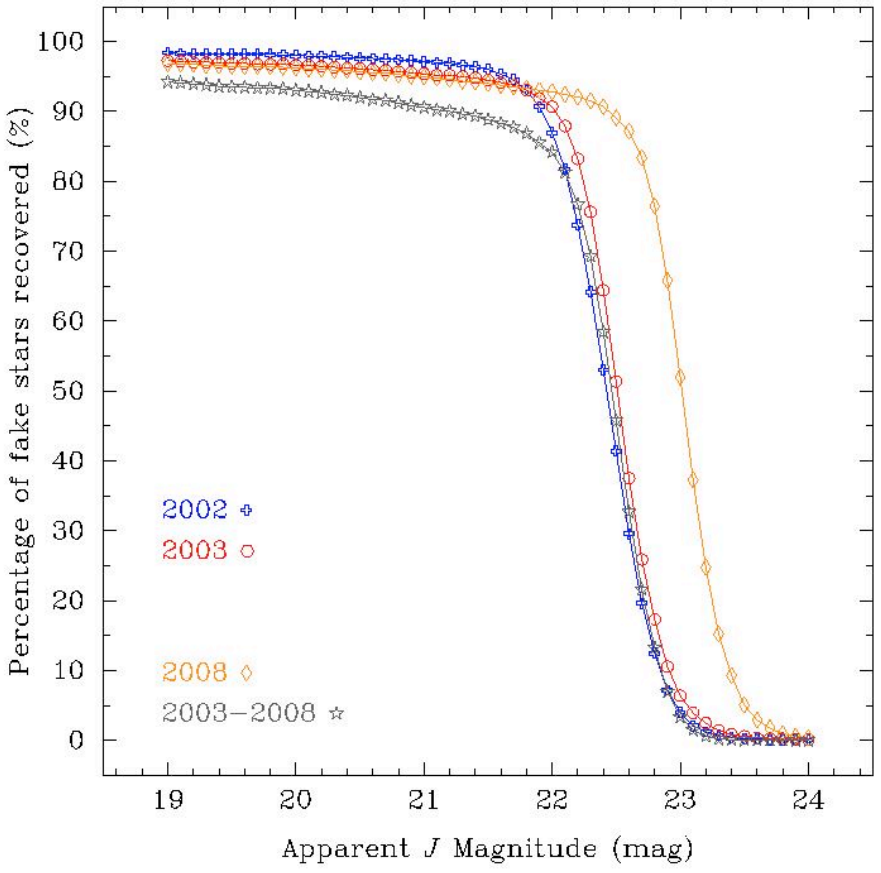
A Candidate?



GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

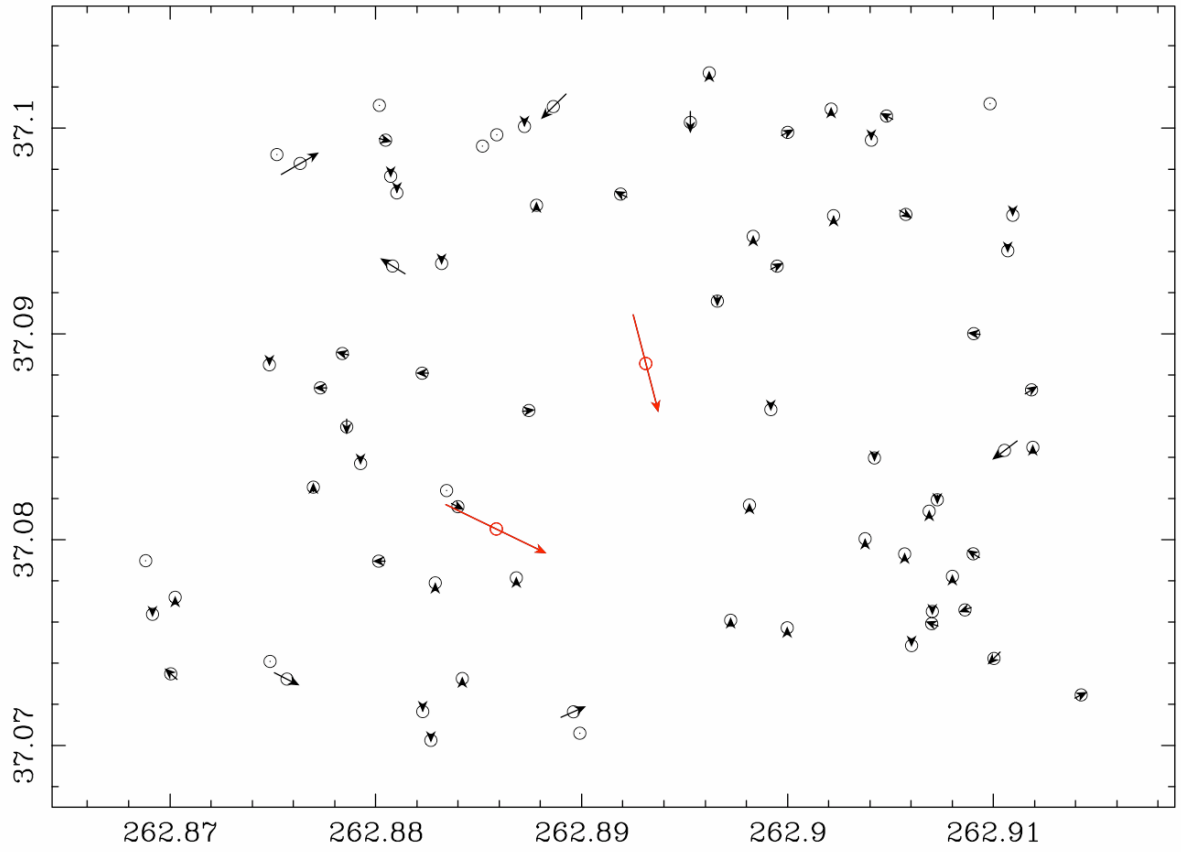
No Candidate ☹





GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

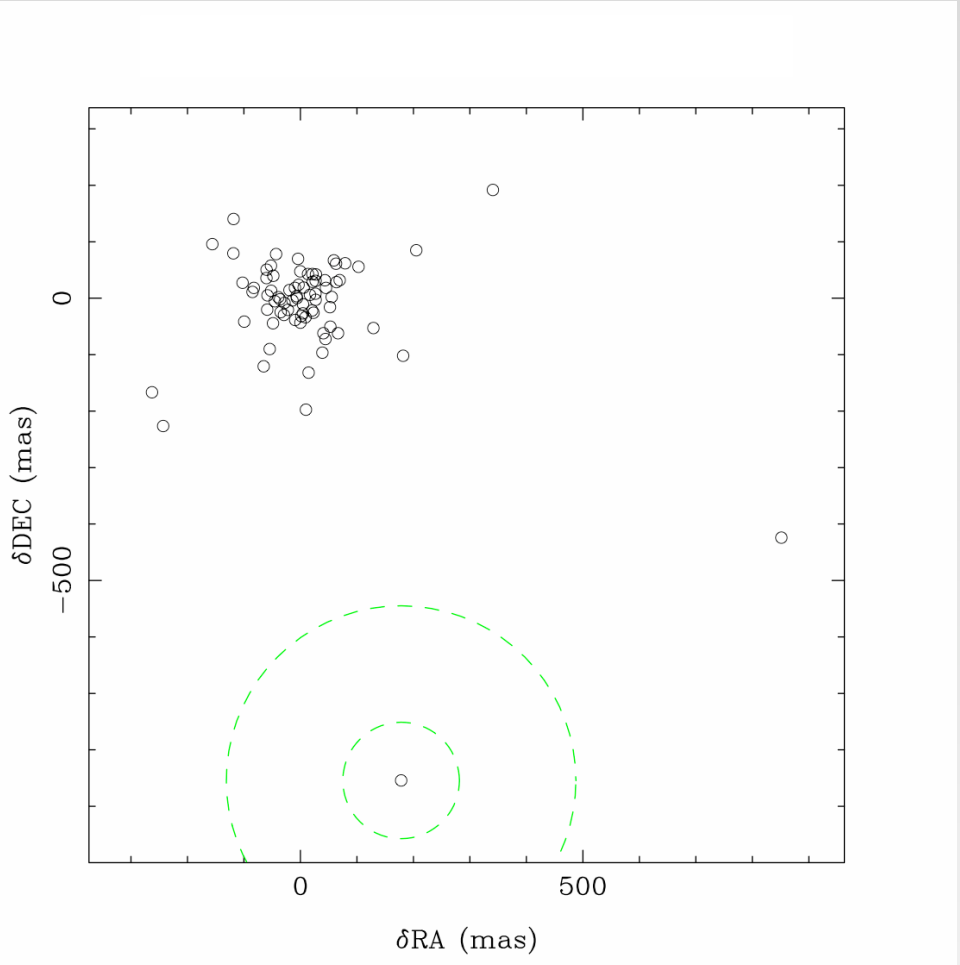
Another Candidate?

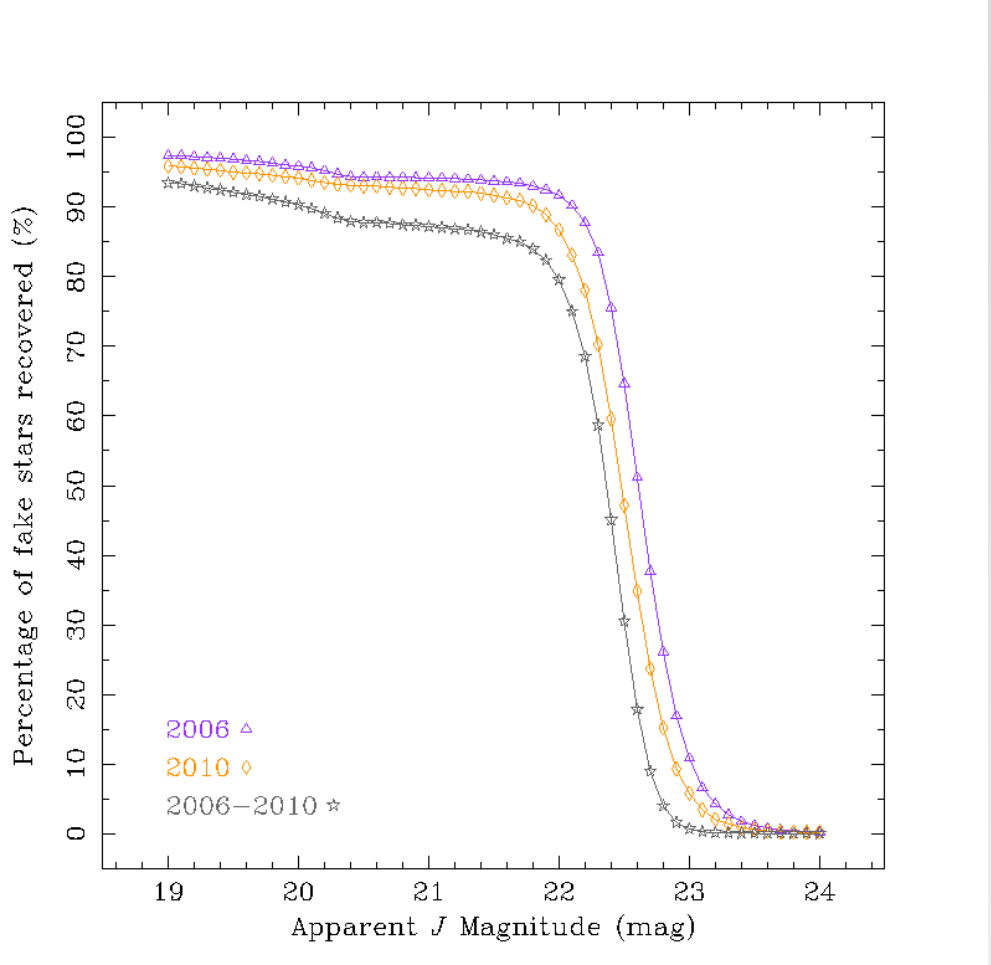


- $M_{WD} \sim 0.7\ M_{\odot}$
- $M_{MS} \sim 3.2\ M_{\odot}$
- $M_{MS} / M_{WD} \sim 4.5$
- $t_{tot} \sim 1.3$ Gyrs
- d ~ 50 pc
- ~ 36” away → $r_{WD} \sim 1850$ AU
- $r_{MS} \sim 400$ AU

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

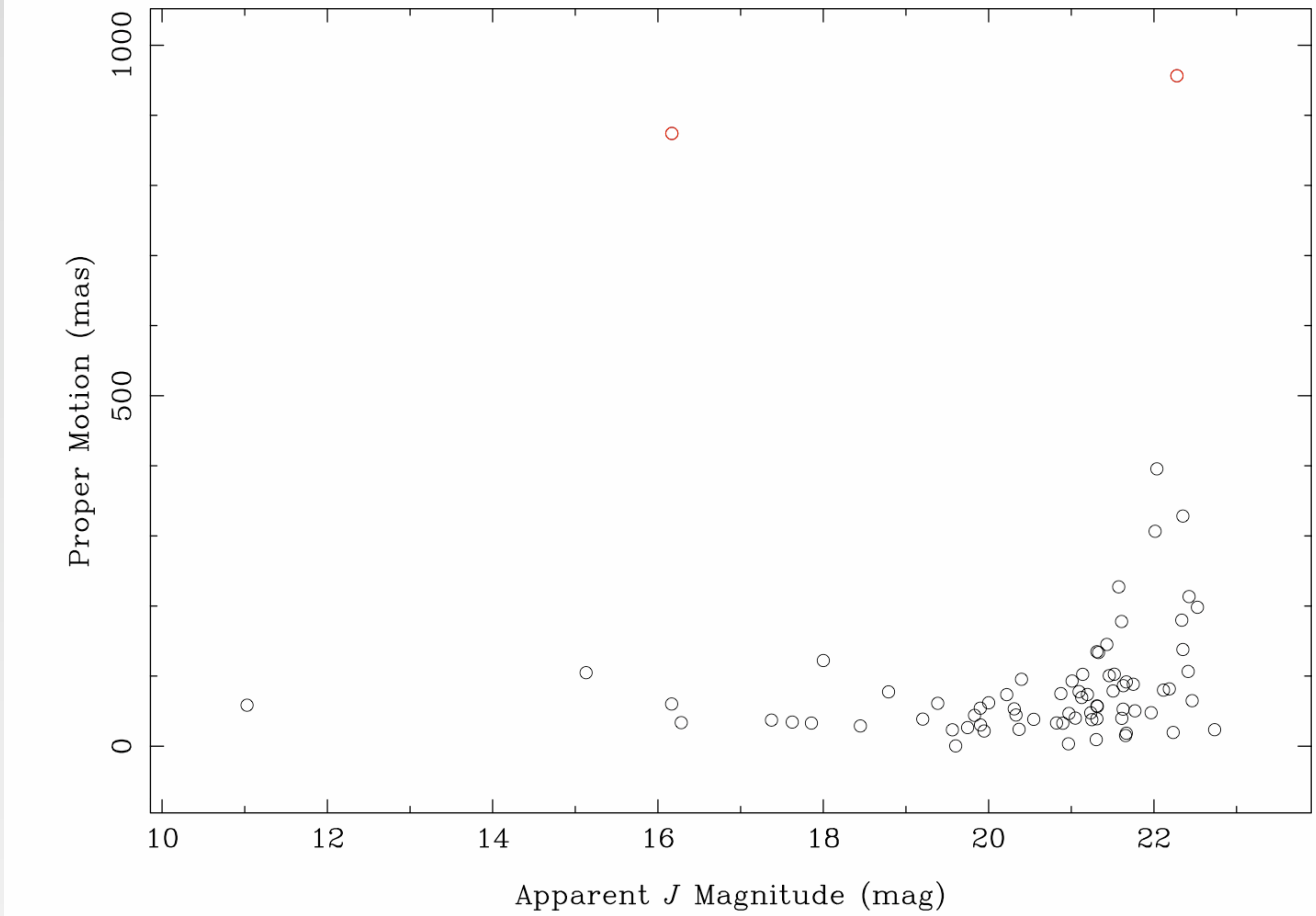
Perhaps?





GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Perhaps?



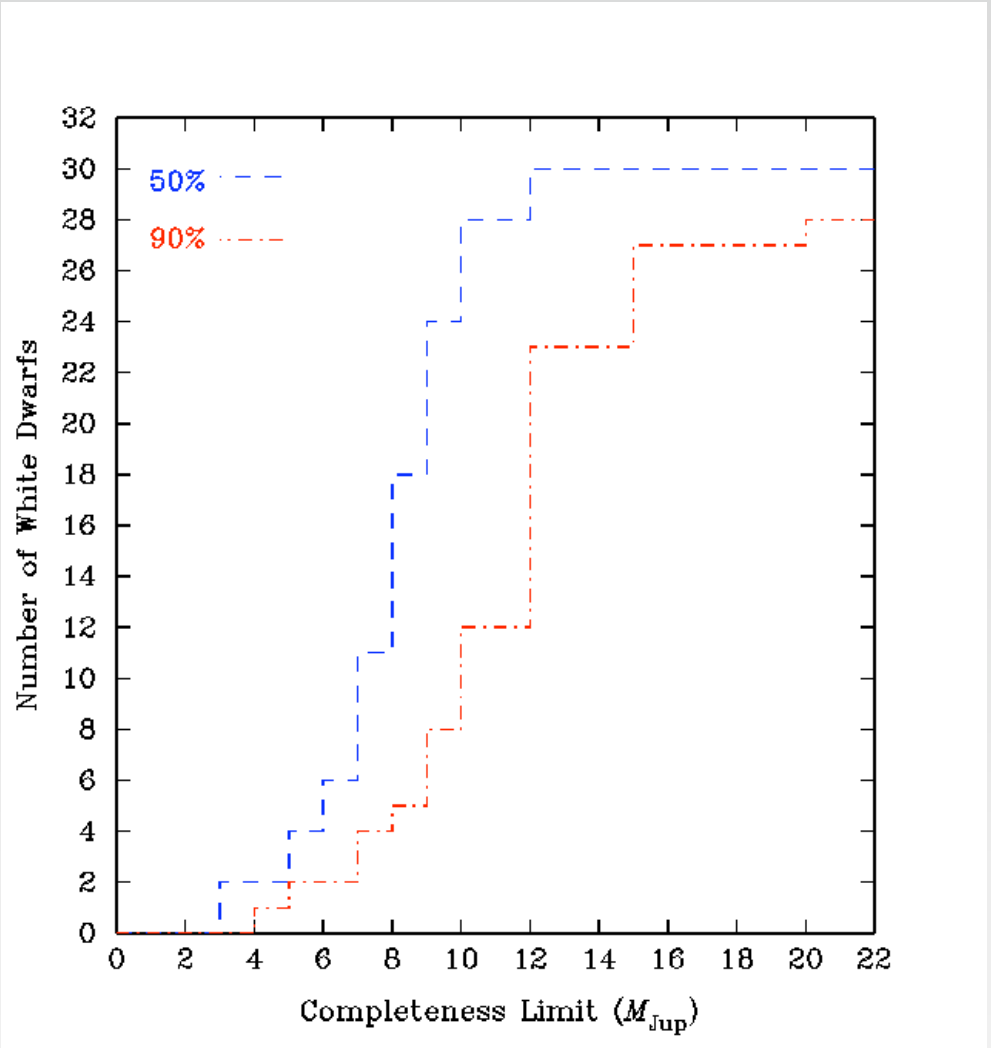
GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

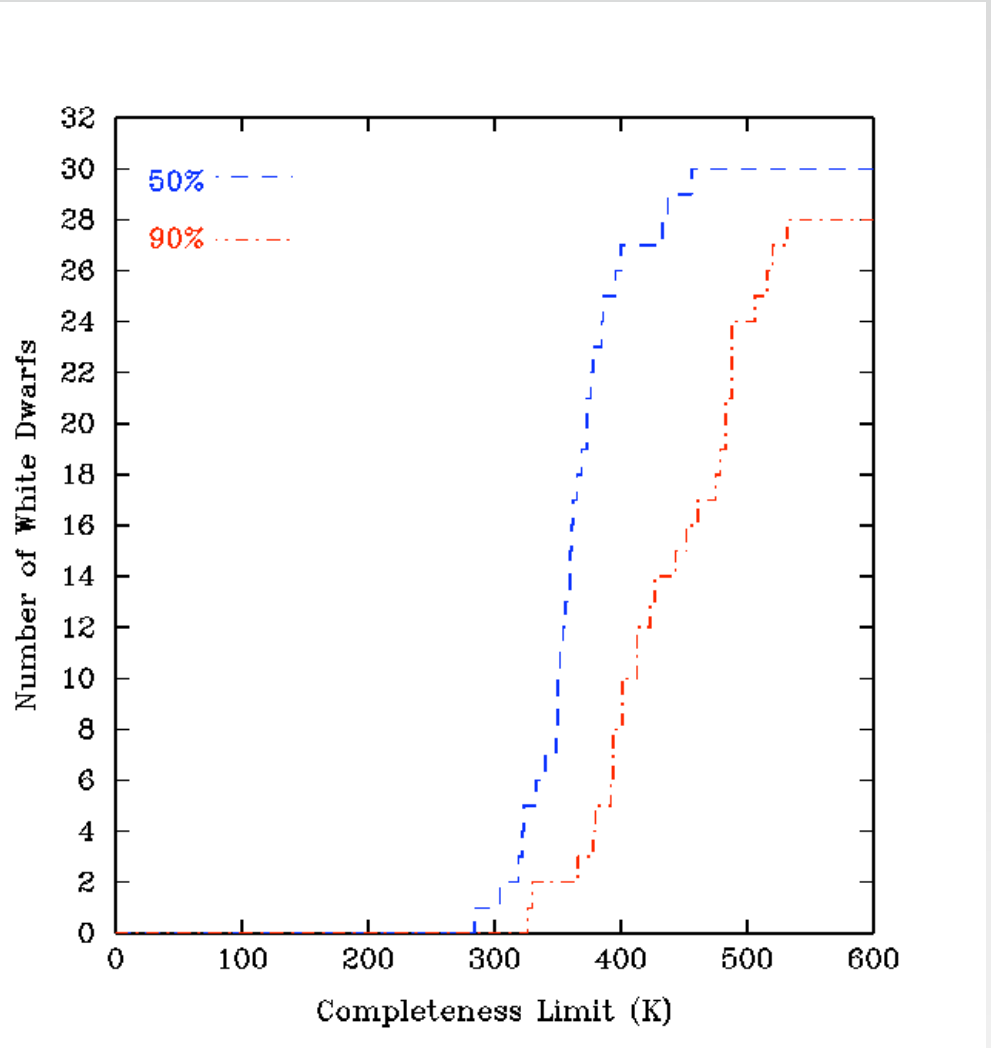
Latest Results

White Dwarf	Type	Age [Gyrs]	50% M [M_{Jup}]	50% T [K]	WD Orbit [AU]	MS Orbit [AU]
WD0115+159	DQ	1.7	8 ± 1	380	46 - 675	11 - 160
WD0208+396	DAZ	2.6	9 ± 1	360	50 - 758	14 - 138
WD0644+375	DA	2.1	8 ± 1	360	46 - 652	17 - 236
WD1055-072	DC	3.3	9 ± 1	340	36 - 503	8 - 103
WD1134+300	DA	0.37	3 ± 1	350	46 - 664	9 - 127
WD1647+591	DAV	0.91	5 ± 1	350	33 - 372	7 - 77
WD1900+705	DAP	1.1	5 ± 1	350	39 - 452	8 - 89
WD1953-011	DAP	2.1	8 ± 1	360	34 - 509	7 - 111
WD2007-219	DA	1.4	7 ± 1	370	55 - 831	12 - 189
WD2326+049	DAZ	1.1	6 ± 1	370	41 - 396	9 - 89

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

More Results





GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

More Results

- The DODO survey can detect companions ≥ 500 K around all targets

- ≤ 4% of white dwarfs have substellar companions with T_{eff} ≥ 500 K between projected physical separations of 60 - 200 AU (20 - 45 AU around MS progenitors.)

- ≤ 8% of white dwarfs have companions with masses above the deuterium burning limit (~13 M_{jup})

- ≤ 9% have companions with masses ≥ 10 M_{Jup}

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Other surveys

Survey	Targets	Number of targets	Limit (M_{Jup})	Separation (AU)	Frequency of companions (%)
McCarthy & Zuckerman (2004)	G K M	102	>12	75–300	1 ± 1
		178	>30	140–1200	0.7 ± 0.7
			5-10	75–300	<3
Farihi et al. (2005)	White dwarfs	261	>52	100–5000	< 0.5
		86	>21	50–1100	< 0.5
Allen et al. (2007)	M7–L8	132	>52	40–1000	< 2.3
Lafrenière et al. (2007)	F G K M	85	13-40	25–250	< 5.6
Nielsen et al. (2008)	A F G K M	60	>4	20–100	<20

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Future Work

- Larger sample size
- Deeper images
- First epoch images for 10 new targets
- Watch this space!