Exploring the giant planet - brown dwarf connection with astrometry

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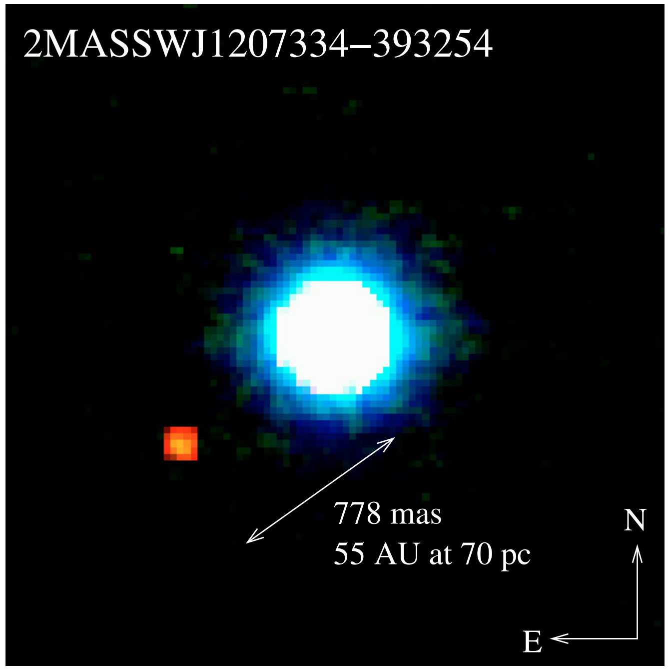
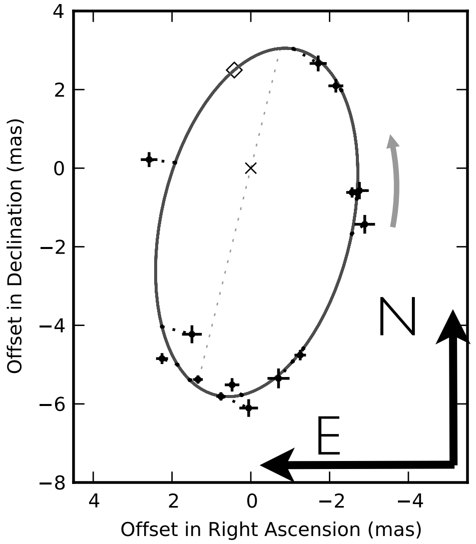
IS MASS A GOOD DEMOGRAPHIC INDICATOR ?



"first image of a planetary mass companion in a different system than our own" (Chauvin et al., A&A, 2005)

$M_1 \sim 25\ M_{Jup}$ $M_2 \sim 5\ M_{Jup}$ mass ratio $q \simeq 0.2$



Planet masses and radii are difficult to measure (in non-transiting systems)

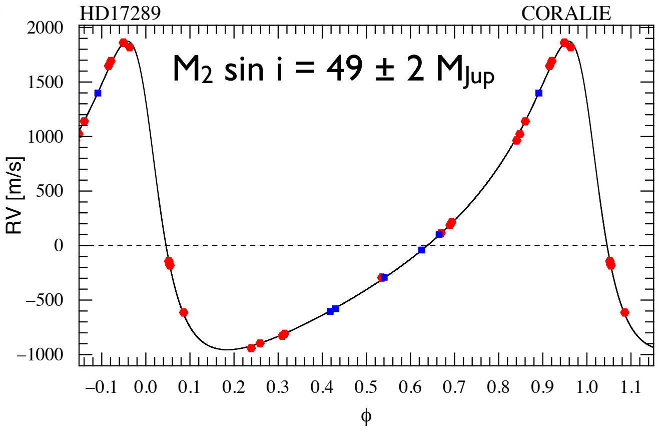
Astrometry gives a good handle on companion masses

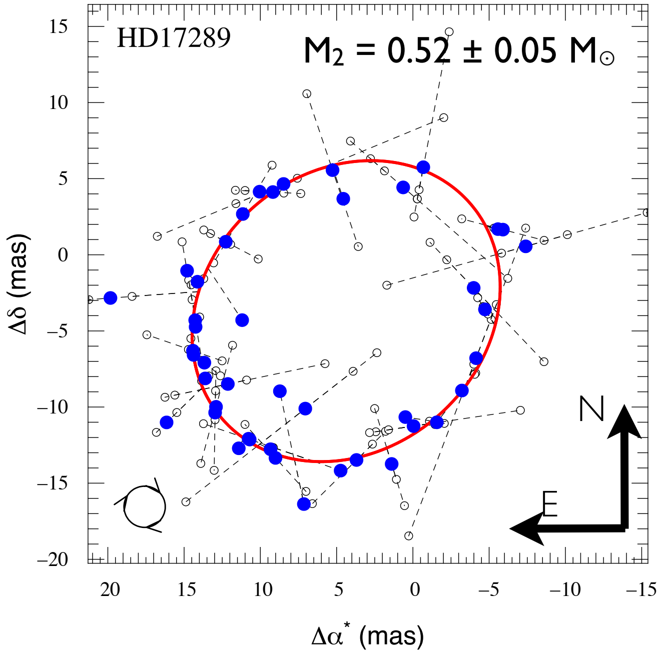
HIGH-MASS TAIL OF PLANET MASSES OVERLAPS WITH SUBSTELLAR COMPANIONS IN BINARY SYSTEMS

CORALIE radial velocity survey of 1647 GK dwarfs:

➔ 20 companions with $M_2 \sin i$ = 13 - 80 M_{Jup}

➔ 10 discarded as M-dwarfs by Hipparcos astrometry (Sahlmann et al., 2011, A&A, 525)

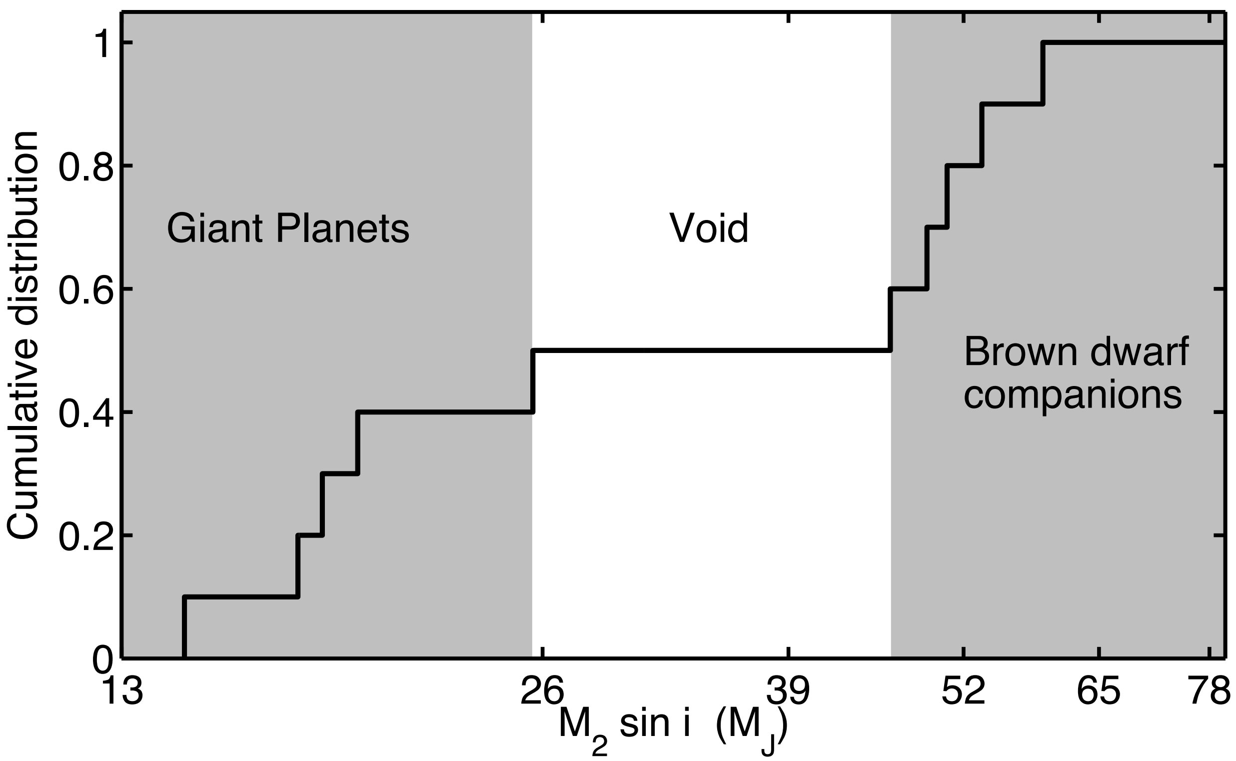




a) 0.6 ± 0.2 % of Sun-like stars have a brown dwarf companion within 10 AU

b) no indication for discontinuity at 13 M_{Jup}

c) mass distribution indicates minimum occurrence at ~25-45 M_{Jup} (see also Grether & Lineweaver 2006)



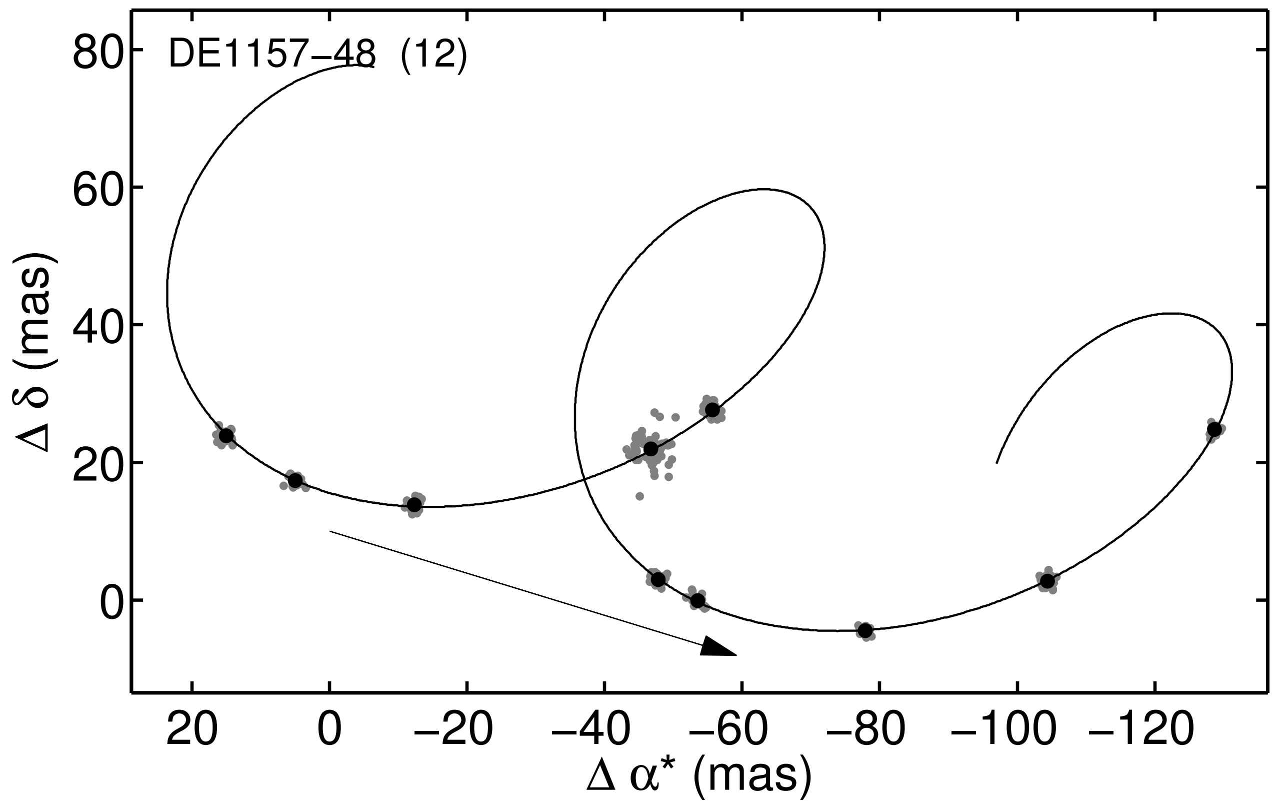
WHAT IS THE PLANET MASS DISTRIBUTION AROUND ULTRACOOL DWARFS ?

➔ Astrometric survey with FORS2 camera at VLT (Sahlmann et al. 2014, Lazorenko et al. 2014)

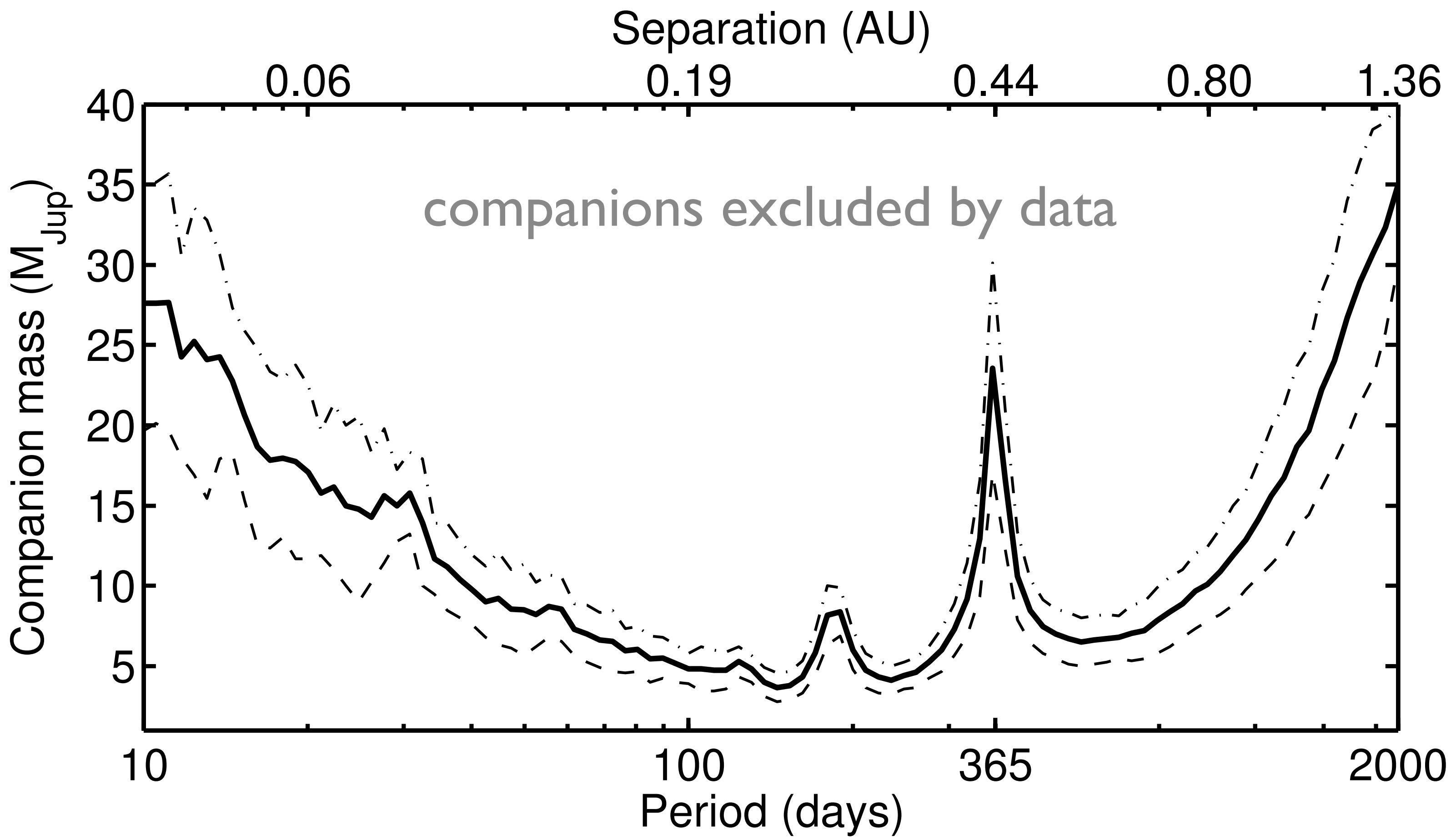
➔ Monitoring 20 nearby late-M and early-L dwarfs since 2010

➔ Long-term astrometic precision ~0.1 milli-arcsec (Lazorenko et al. 2009 & 2011)

➔ sensitive down to Neptune-mass planets in ~1000 day orbits



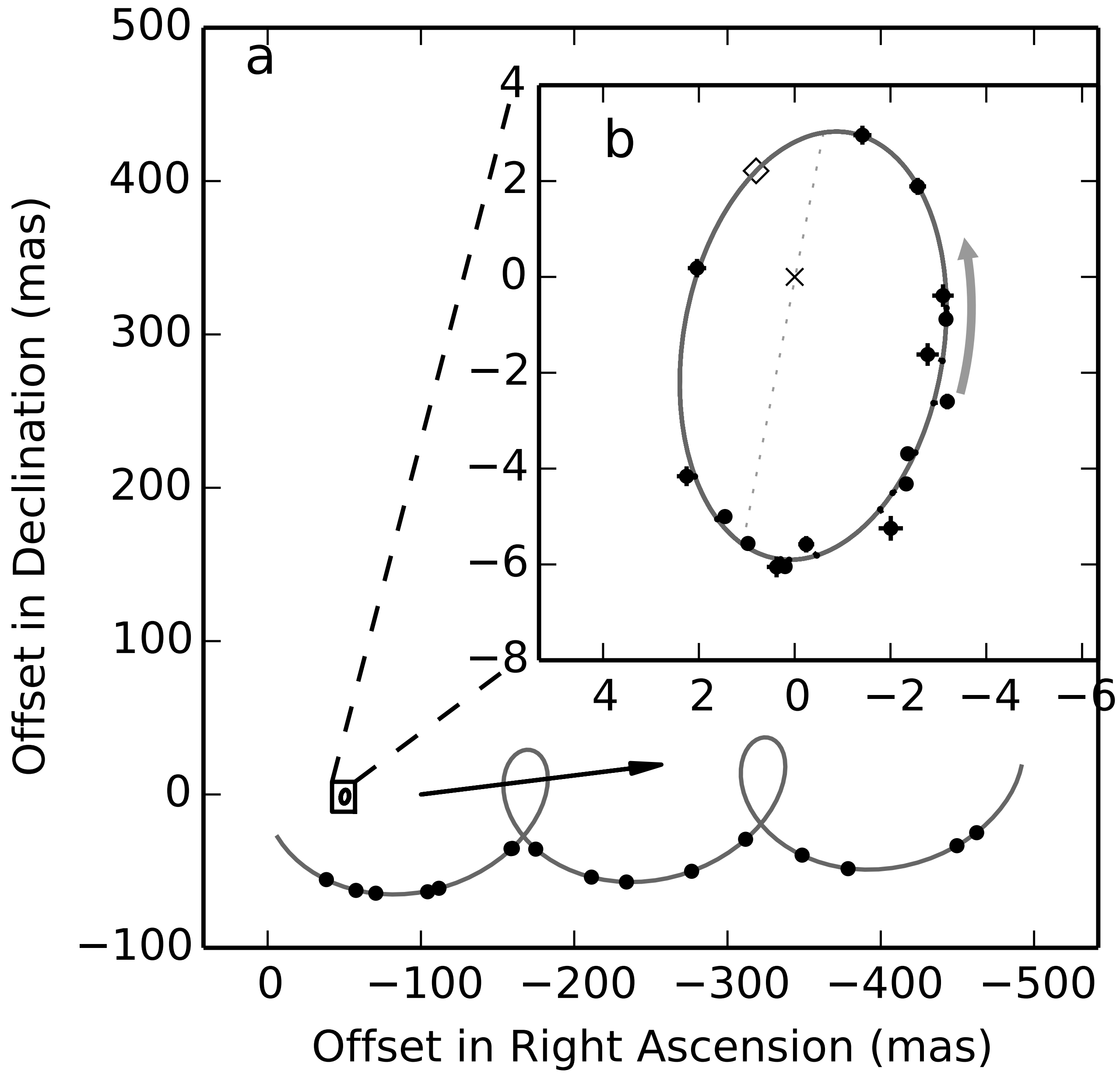
GIANT PLANETS ARE RARE AROUND ULTRACOOL DWARFS (AT ALL SEPARATIONS)



Less than 9 % of M8-L2 dwarfs have a giant planet >5M_{Jup} within 0.1-0.8 AU (Sahlmann et al. 2014)

Ongoing follow-up of planet candidates

DETECTION OF THE ORBIT CAUSED BY A LOW-MASS COMPANION



L1.5 dwarf

P = 247.8 ± 0.6 days
e = 0.36 ± 0.04
α = 4.62 ± 0.12 mas
Parallax = 48.33 ± 0.14 mas

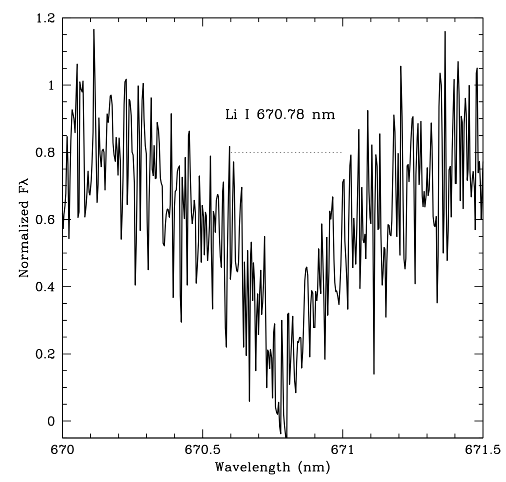
16 epochs
residual RMS 170 μas

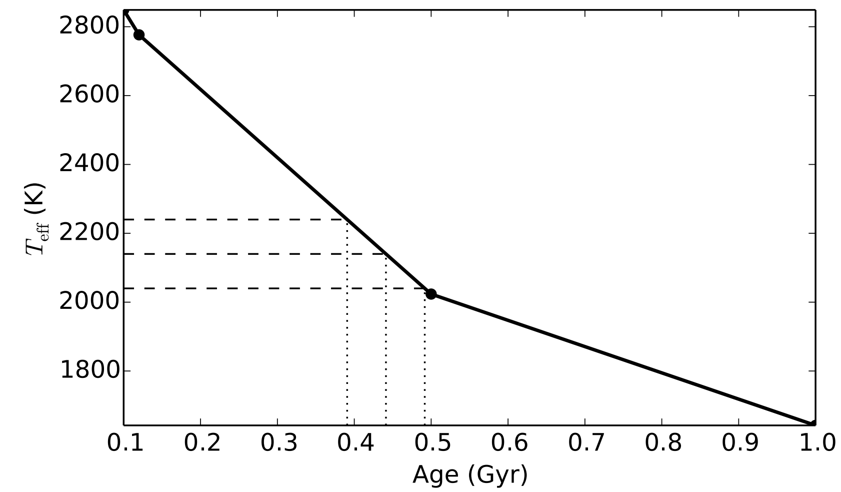
Derived properties depend on age estimate

Sahlmann et al., 2013, A&A 556

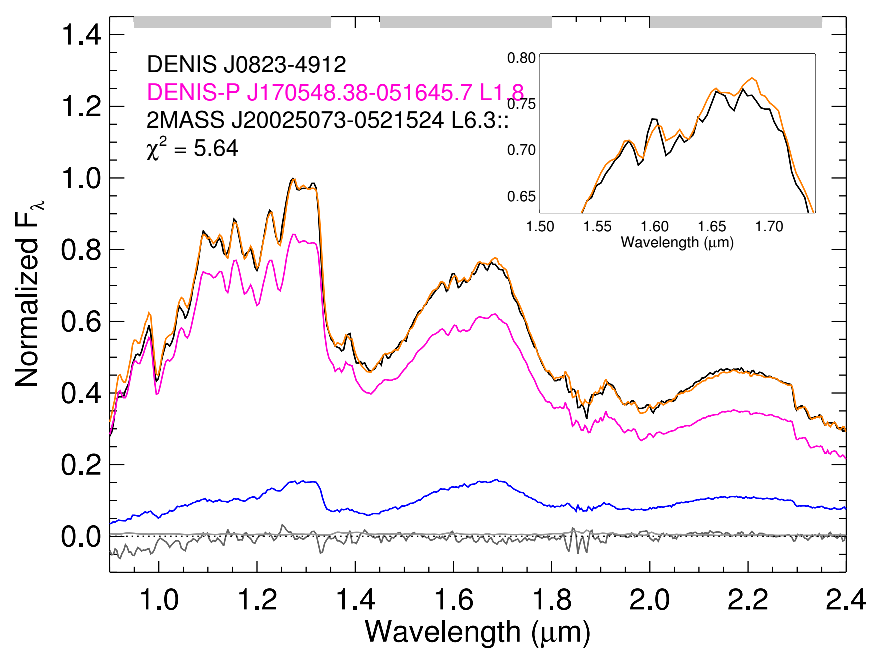
A JUVENILE BINARY BROWN DWARF AT 20.7 PC

Li I absorption detected in optical spectrum ➔ age constraint





spectral binary in the near-infrared
➔ spectral types L1.5 + L5.5
$T_{\rm eff}$ = 2150 ± 100 K and 1670 ± 140 K



Combined astrometric and spectroscopic constraints + evolutionary models:

Age = 80 - 500 Myr

$M_1 \simeq 0.028 - 0.063\ M_\odot$

$M_2 \simeq 0.018 - 0.045\ M_\odot$

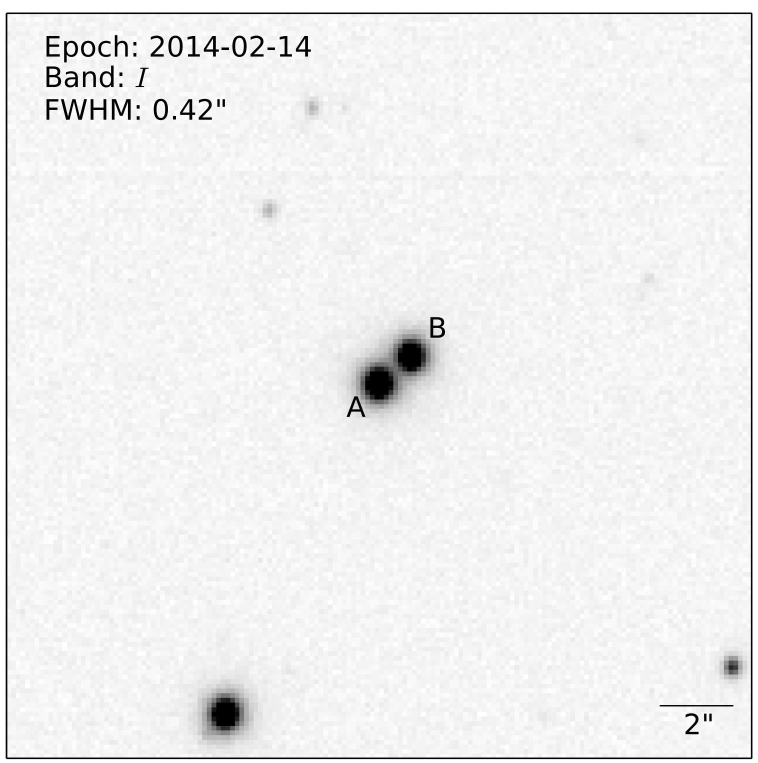
mass ratio $q \simeq 0.64 - 0.74$

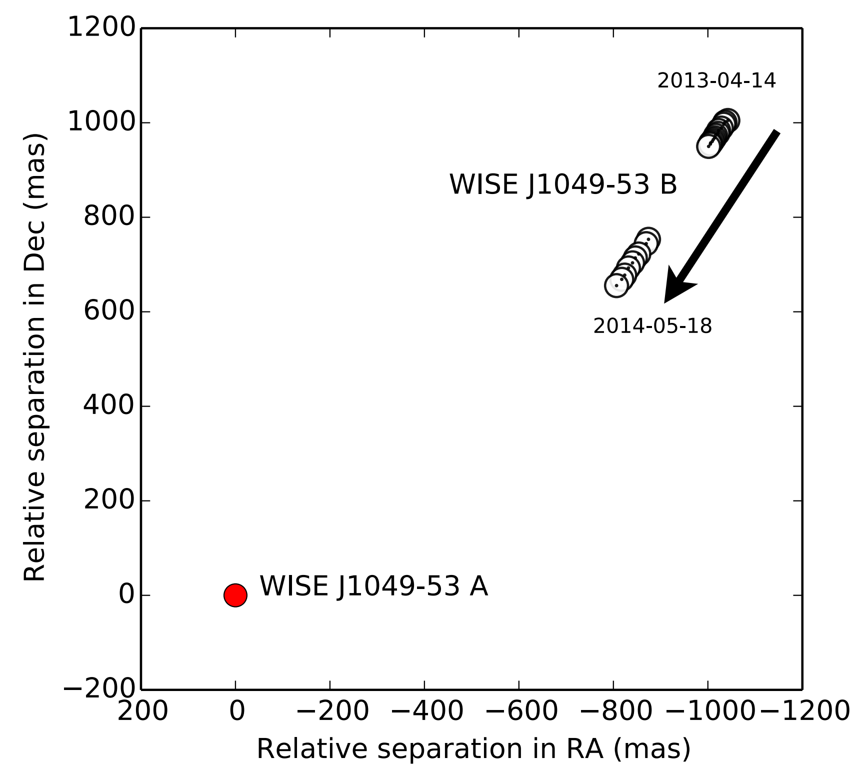
Sahlmann, Burgasser, et al. 2015, A&A

A GIANT PLANET AROUND LUH16 ?

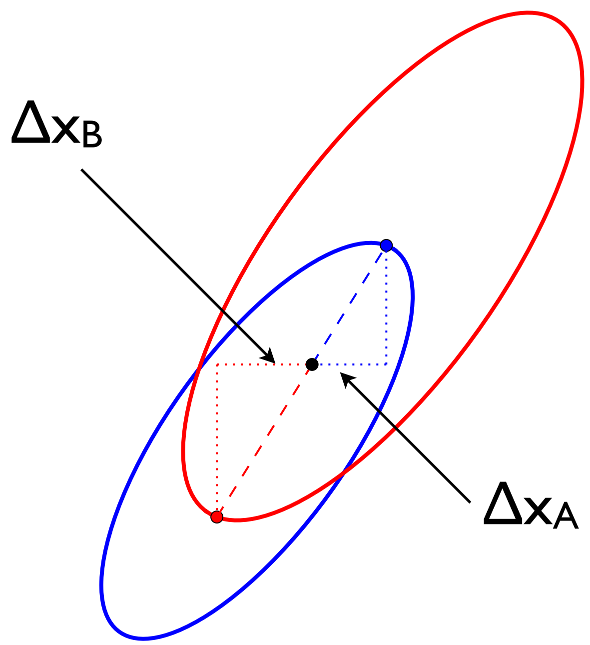
- WISE J104915.57-531906.1 (Luhman 2013)
- 2 pc distance
- ~3 AU binary: L7.5 + T0.5 (Burgasser et al. 2013, Faherty et al. 2014)
- Possible detection of a giant planet in a short-period orbit around one component (Boffin et al. 2014)

- We analysed 22 epochs of public FORS2 data (PI: Boffin) taken over 1 year
- Applied Lazorenko's techniques to obtain astrometry of both components
- Individual fits are poor, data of both components have to be modelled jointly





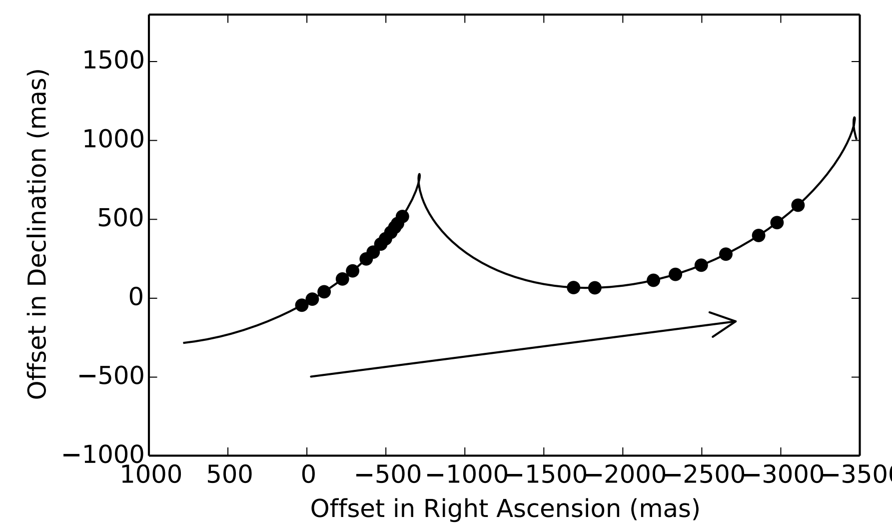
BARYCENTRE FIT IS GOOD AND DETERMINES THE MASS RATIO

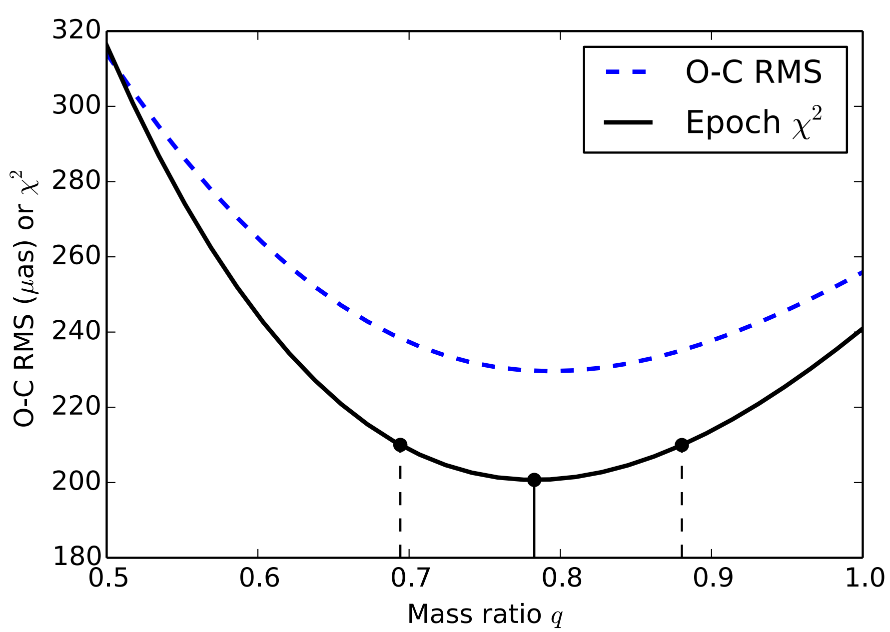


mass ratio $q = M_B / M_A = \Delta x_A / \Delta x_B$

Reconstructed barycentre motion as a function of mass ratio:

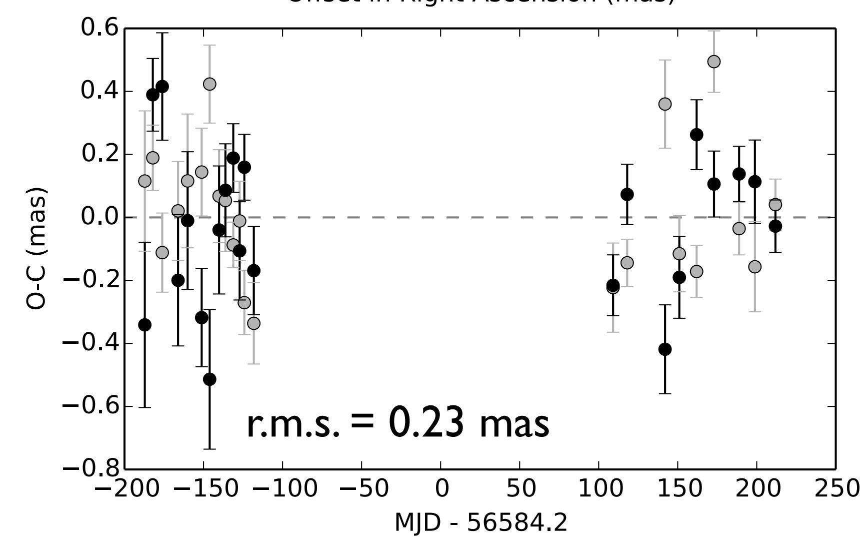
$$\alpha^\star_\gamma = \frac{1}{1+q} \left(\alpha^\star_\mathrm{A} + q\, \alpha^\star_\mathrm{B}\right)$$
$$\delta_\gamma = \frac{1}{1+q} \left(\delta_\mathrm{A} + q\, \delta_\mathrm{B}\right).$$





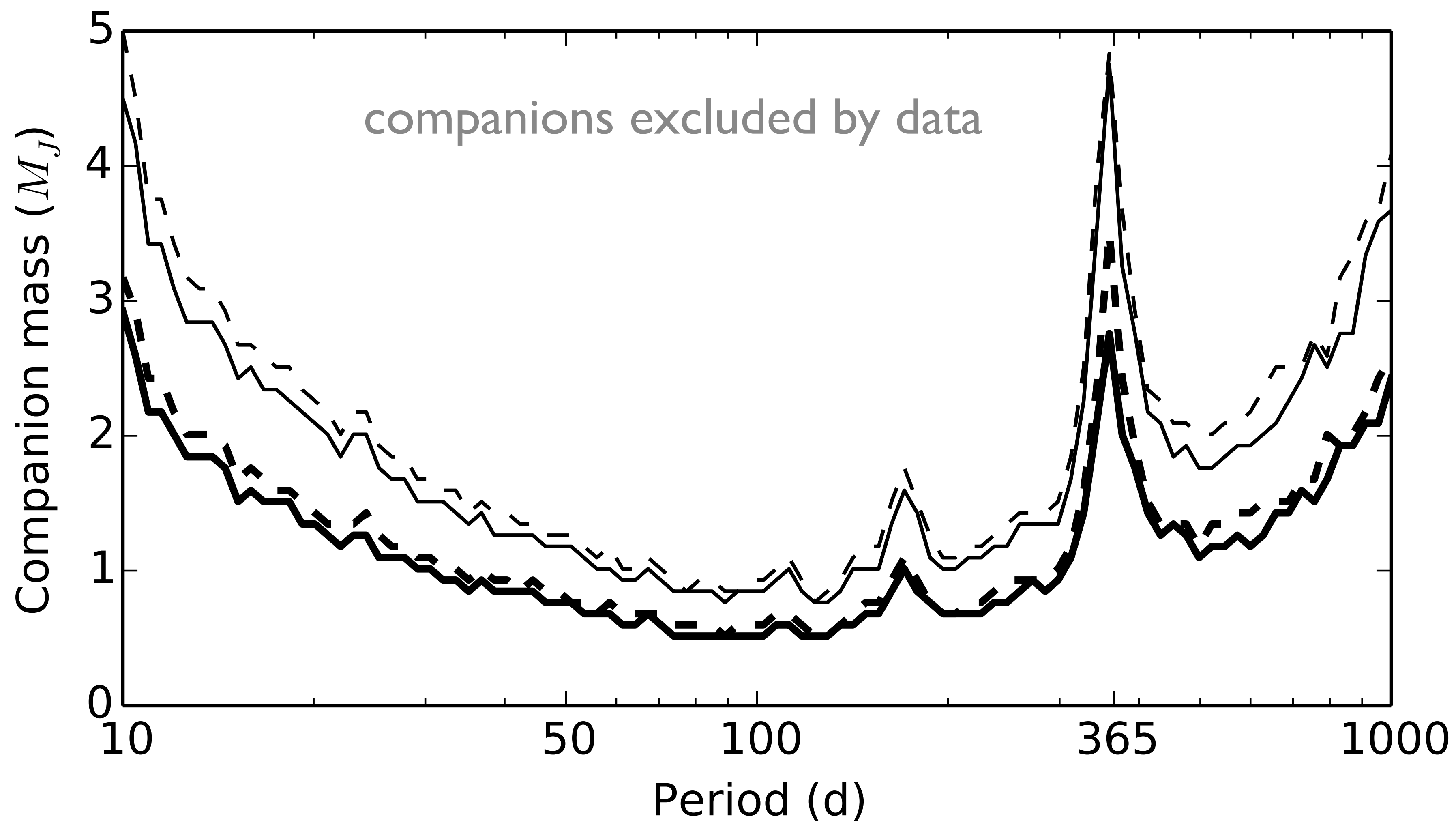
➔ $q = 0.78 \pm 0.10$

direct measurement (no models), independent of distance and orbit



Sahlmann & Lazorenko, submitted, arxiv:1506.07994

NO GIANT PLANET AROUND LUH16, YET

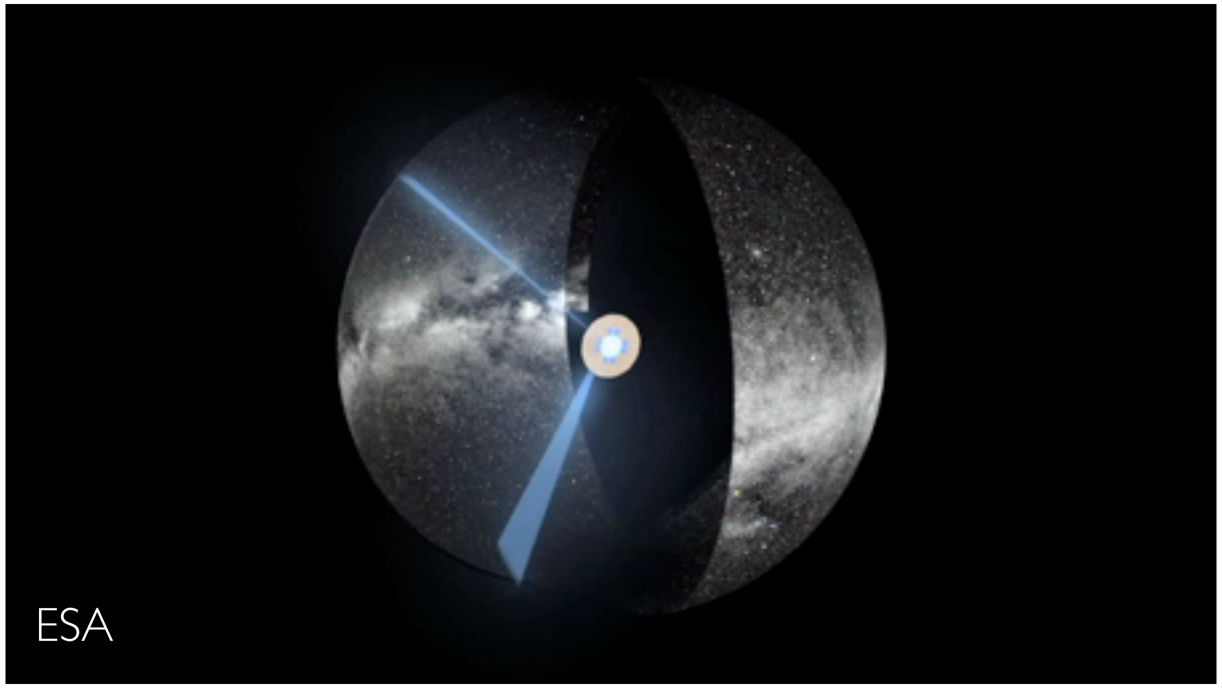


$M_A \simeq 0.060\ M_\odot$ / $M_B \simeq 0.047\ M_\odot$
(3 Gyr)

$M_A \simeq 0.030\ M_\odot$ / $M_B \simeq 0.023\ M_\odot$
(0.5 Gyr)

Sahlmann & Lazorenko, submitted, arxiv:1506.07994

GAIA'S EXOPLANET AND BD YIELD



5-year all-sky survey, $G < 20$ mag

Gaia will deliver high-precision astrometry of 1000 million stars (+ photometry, spectroscopy)

Nominal mission began July 2014

Gaia will discover thousands of giant extrasolar planets with masses higher than Saturn and periods shorter than ~2000 days.
(Casertano et al. 2008, Sozzetti et al., 2014, Perryman at al., 2014, Sahlmann, Triaud & Martin 2015)

For Sun-like stars, Gaia astrometry will detect 30 M_{Jup} companions out to distances of ~0.8 kpc and 60 M_{Jup} out to ~1.7 kpc

Gaia will uniformly yield the masses and orbital parameters of hundreds of companions in the brown-dwarf mass range.

CONCLUSIONS

Mass alone is not a good demographic indicator:
A 35 M_{Jup} companion to a Sun-like star may have formed like a planet or like a binary.

Astrometric surveys of ultracool dwarfs are sensitive to giant planets and reveal binaries with planetary-mass components. Super-Jupiters are rare at all separations.

The mass ratio of the 2-pc binary brown dwarf LUH16 is 0.78 +/- 0.10.
There is no indication for a giant planet in a short-period orbit around either component.

Gaia's survey will provide a comprehensive census of substellar companions more massive than Saturn in the solar neighbourhood.

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