Exploring the giant planet - brown dwarf connection with astrometry

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

\[ M_1 \sim 25 \, M_{\text{Jup}} \quad M_2 \sim 5 \, M_{\text{Jup}} \quad \text{mass ratio } q \sim 0.2 \]

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

Astrometry gives a good handle on companion masses
Coralie radial velocity survey of 1647 GK dwarfs:
→ 20 companions with $M_2 \sin i = 13 - 80 \, M_{\text{Jup}}$
→ 10 discarded as M-dwarfs by Hipparcos astrometry (Sahlmann et al., 2011, A&A, 525)

a) $0.6 \pm 0.2 \%$ of Sun-like stars have a brown dwarf companion within 10 AU
b) no indication for discontinuity at $13 \, M_{\text{Jup}}$
c) mass distribution indicates minimum occurrence at $\sim 25-45 \, M_{\text{Jup}}$ (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 astrometric precision ~0.1 milli-arcsec (Lazorenko et al. 2009 & 2011)
➔ sensitive down to Neptune-mass planets in ~1000 day orbits

DE1048−52  (11)

DE1157−48  (12)

DE1159−52  (13)

DE1253−57  (14)

DE1520−44  (15)

DE1705−54  (16)

DE1733−16  (17)

DE1745−16  (18)

DE1756−45  (19)

DE1756−48  (20)

Fig. 6. Astrometric motions of targets number 11–20 in the sky. Display equivalent to Fig. 5.
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
L1.5 dwarf

\[ P = 247.8 \pm 0.6 \text{ days} \]
\[ e = 0.36 \pm 0.04 \]
\[ \alpha = 4.62 \pm 0.12 \text{ mas} \]
\[ \text{Parallax} = 48.33 \pm 0.14 \text{ mas} \]

16 epochs
residual RMS 170 \( \mu \text{as} \)

Derived properties depend on age estimate
For every individual spectral fit, we also computed bolometric – 2MASS Schmidt et al. (2010) relation between spectral type and SDSS available binary templates and the F-test confidence. E results are summarised in Table 2, which also lists the number of age values with uncertainties like in Burgasser et al. (2010). The F-test shows the best-fit young binary template, a combination of DENIS-P J170548.38-051645.7 (DE1705 shows the best-fit young binary template, a combination of

DE0823 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

$T_{\text{eff}} = 2150 \pm 100$ K and $1670 \pm 140$ K

Combined astrometric and spectroscopic constraints + evolutionary models:

Age = 80 - 500 Myr

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

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

mass ratio $q \approx 0.64 - 0.74$

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
mass ratio \( q = \frac{M_B}{M_A} = \frac{\Delta x_A}{\Delta x_B} \)

Reconstructed barycentre motion as a function of mass ratio:

\[
\begin{align*}
\alpha^*_\gamma &= \frac{1}{1+q} (\alpha^*_A + q \alpha^*_B) \\
\delta_\gamma &= \frac{1}{1+q} (\delta_A + q \delta_B).
\end{align*}
\]

\( q = 0.78 \pm 0.10 \)

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

Sahlmann & Lazorenko, submitted, arxiv:1506.07994
NO GIANT PLANET AROUND LUH16, YET

companions excluded by data

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

$M_A \approx 0.030 M_\odot / M_B \approx 0.023 M_\odot$
(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 \( \sim 2000 \) days.


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

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