Extrasolar Planet Science with High-Precision Astrometry

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High-precision astrometry is powerful

- Yields complete information, sensitive to orbit inclination
  - Ideal tool to determine the accurate planet mass distribution

- Does not require spectral lines
  - Possible to target faint objects, e.g. brown dwarfs

- Less sensitive to activity than radial velocity & transit method
  - Adapted to the search for planets around young/active stars
High-precision astrometry is powerful, but yet limited by the achievable precision.
astrometry constrains the true companion mass of RV companions

- radial velocities yield $P, T_0, e, \omega, K_1$
- HIPPARCOS astrometry (van Leeuwen, 2007)
- $i$ and $\Omega$ from astrometry

\[
\begin{align*}
M_2 \sin i &= 49 \pm 2 \, M_{\text{Jup}} \\
i &= 173.2 \pm 0.5 \, \text{deg} \quad \rightarrow \quad M_2 &= 0.52 \pm 0.05 \, M_{\odot}
\end{align*}
\]

Brown dwarf ?

M-dwarf !

Sahlmann et al., 2011, A&A, 525
the upper mass limit for planets orbiting Sun-like stars revealed with astrometry

- **RV**: 20 candidate brown dwarf companions in uniform sample (CORALIE)
- **Astrometry**: 10 companions have true masses > 80 \( M_{\text{Jup}} \), thus are M-dwarfs
  \( \Rightarrow \) 10 BD companions remain in the sample of 1647 stars.
  \( \Rightarrow \) 0.6 ± 0.2 % of Sun-like stars have a brown dwarf companion within 10 AU.

\[ \text{true masses?} \]
\[ \Rightarrow \mu \text{as astrometry} \]

\[ \Rightarrow \text{upper planet mass limit at } \sim 25\text{-}30 \, M_{\text{Jup}} \]

Sahlmann et al., 2011, A&A, 525  Sahlmann et al., 2011, IAUS 276
an IR-interferometer can realise 10 μas astrometry

single-reference relative astrometry within a narrow field (~30") in K-band

interference fringe separation in delay space is proportional to angular separation

atmospheric limit: 10 μas for 30 min integration and a 100 m baseline (Shao & Colavita, 1992)

⇒ sufficient for exoplanet detection around one of the stars
Exoplanet search with PRIMA

PRIMA is the dual-feed facility of the VLTI  
Delplancke et al., 2006

ESPRI = MPIA Heidelberg  
+ LSW Heidelberg  
+ Observatoire de Genève

targets: hosts of RV planets,  
young stars, nearby main-sequence stars

accuracy requirement: 10 - 100 µas

under commissioning at Paranal observatory  
Launhardt et al., 2008
binary star observations with PRIMA

⇒ precision is sufficient

but biases are yet too large for the planet search

work in progress ...

Sahlmann et al., in prep.
A FORS2/VLT search for planets around late-M and L dwarfs

Are the conditions for planet formation met around ultra-cool dwarfs?
FORS2/VLT is capable of 100 micro-arcsec astrometry

**Principles**

Lazorenko & Lazorenko 2004, Lazorenko 2006

- optical imaging with an exquisite camera + large telescope
- large number of reference stars
- detailed modelling of PSF distortions and atmospheric image motion

**Performance**

Lazorenko et al. 2007, 2009, 2011

- precision of ~50 µas on time scales of days-years
- refuted planet around VB10

**Planet search survey of 20 targets (ongoing)**

20 late-M and early-L dwarfs close to the galactic plane within 30 pc

2-year programme: 10 epochs per target
15 nights of FORS2 (2010-2012)
measuring parallax and proper motion

Dwarf 04

average epoch uncertainty: 110 μas
residual dispersion: 140 μas

parallax 60.87 +/- 0.06 mas (relative)
proper motion RA -234.31 +/- 0.09 mas/yr
proper motion DE 85.48 +/- 0.07 mas/yr
1. The long-term accuracy is $< 130 \, \mu\text{as}$ per epoch. **Better than GAIA for faint targets!**

2. Exclude planets more massive than Jupiter in intermediate periods ($\sim 50$-$400$ days) for several targets.

[Sahlmann et al., in prep.]
Conclusions

High-precision astrometry is powerful: revealed upper-mass limit for planets around Sun-like stars

Better than 1 milli-arcsec astrometry is required to reach into the Jupiter-mass domain:

1. PRIMA/VLTI has the potential: 30 micro-arcsec precision demonstrated, but ESPRI planet search inhibited by systematic errors limiting the astrometric accuracy to > 3 mas (so far!)

2. FORS2/VLT realises 130 micro-arcsec accuracy -> exploring the population of planets around ultra-cool dwarfs (+ ultra-precise distances + BD binaries)

General-user ground-based facilities for high-precision astrometry can deliver great science. Synergies (e.g. preparation + follow up) with fixed-duration space missions (GAIA).

Unique capabilities present at ESO: Imaging with (extremely) large telescopes + Interferometer