Extrasolar Planet Science with High-Precision Astrometry

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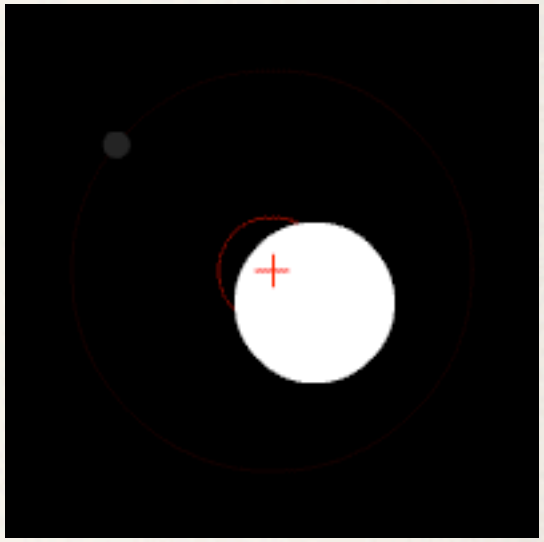
high-precision astrometry is powerful

yields complete information, sensitive to orbit inclination

-> ideal tool to determine the accurate planet mass distribution

does not require spectral lines

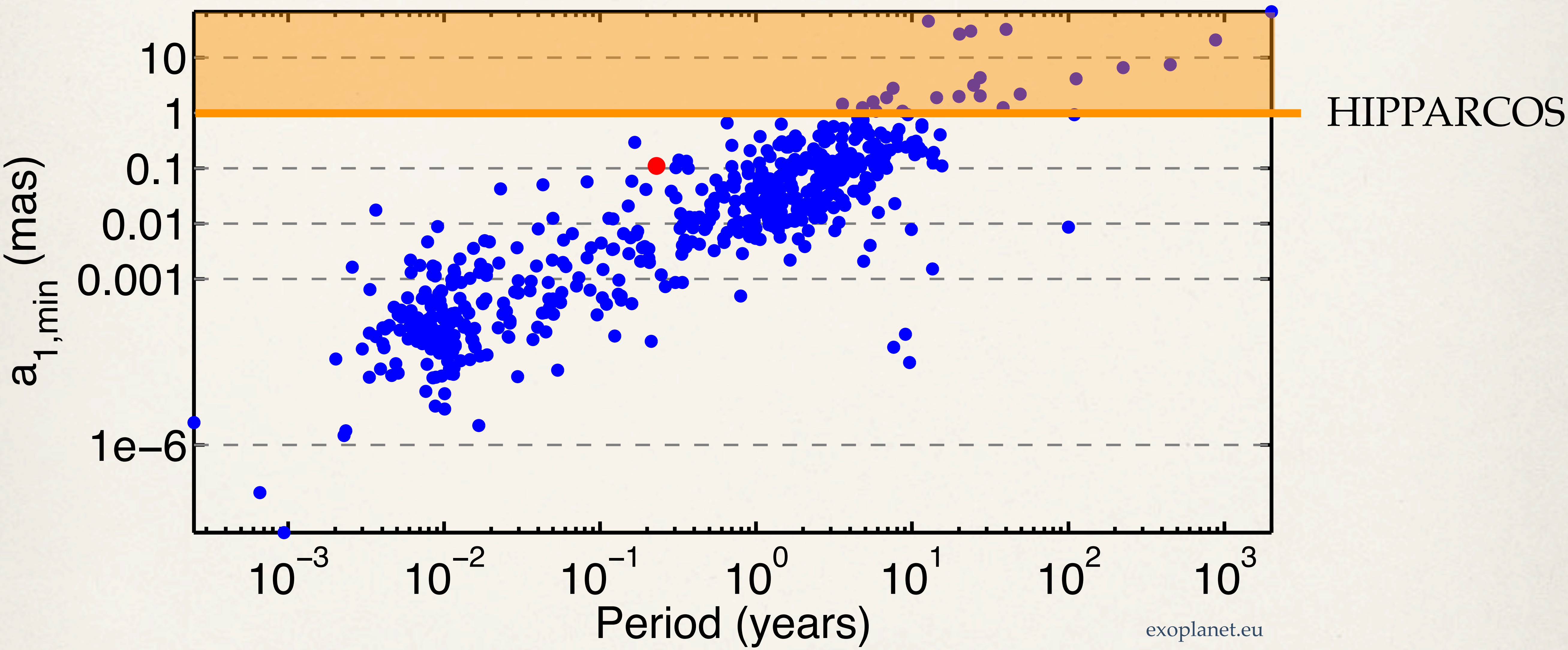
-> possible to target faint objects, e.g. brown dwarfs



less sensitive to activity than radial velocity & transit method

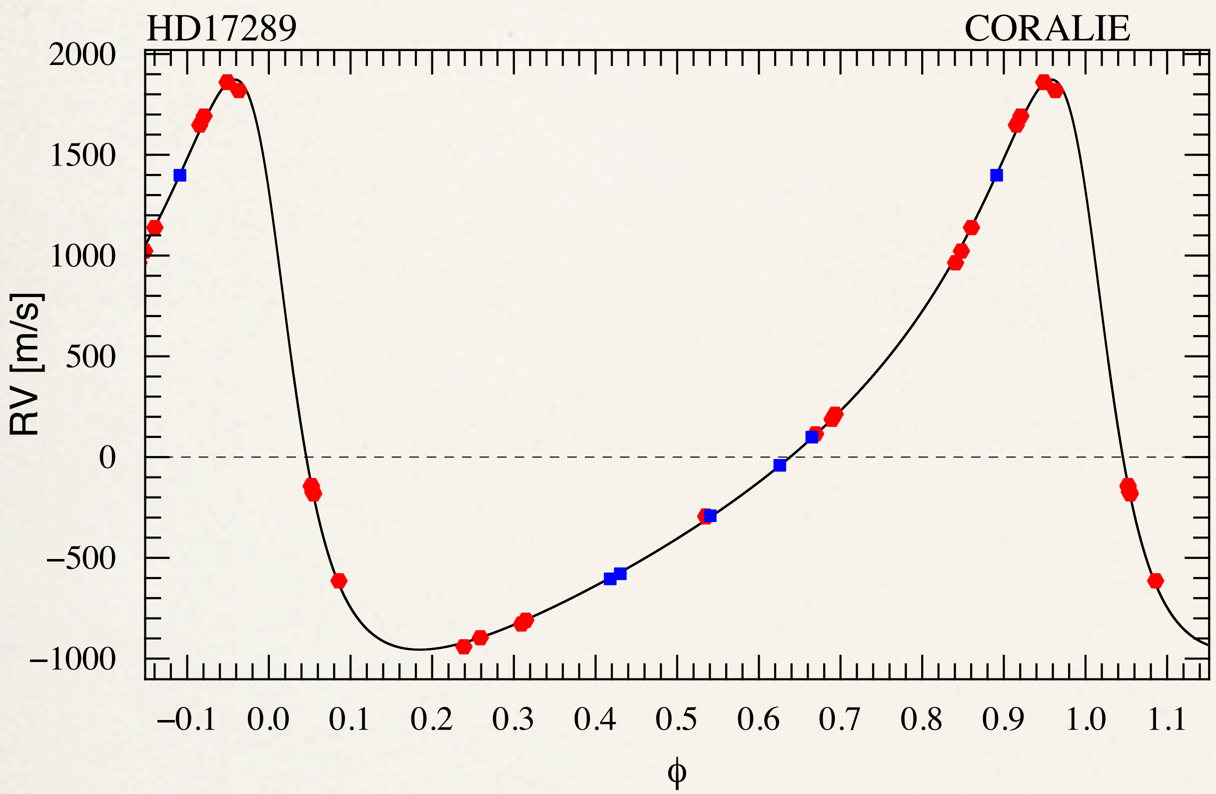
-> adapted to the search for planets around young/active stars

high-precision astrometry is powerful, but yet limited by the achievable precision

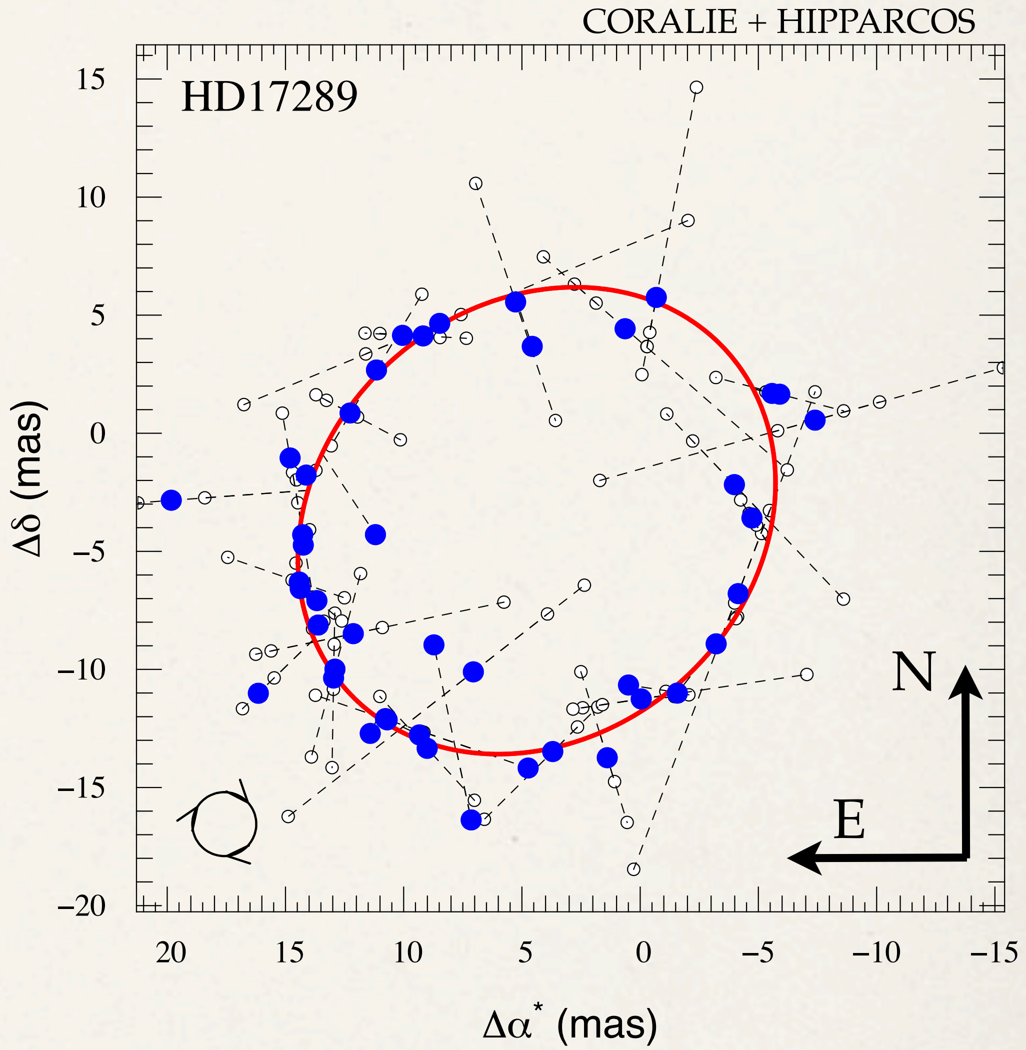


astrometry constrains the true companion mass of RV companions

- radial velocities yield P, T_0, e, ω, K_1
- HIPPARCOS astrometry (van Leeuwen, 2007)
- i and Ω from astrometry



$M_2 \sin i = 49 \pm 2\ M_{Jup}$



$i = 173.2 \pm 0.5$ deg → $M_2 = 0.52 \pm 0.05\ M_\odot$

Brown dwarf ?

M-dwarf !

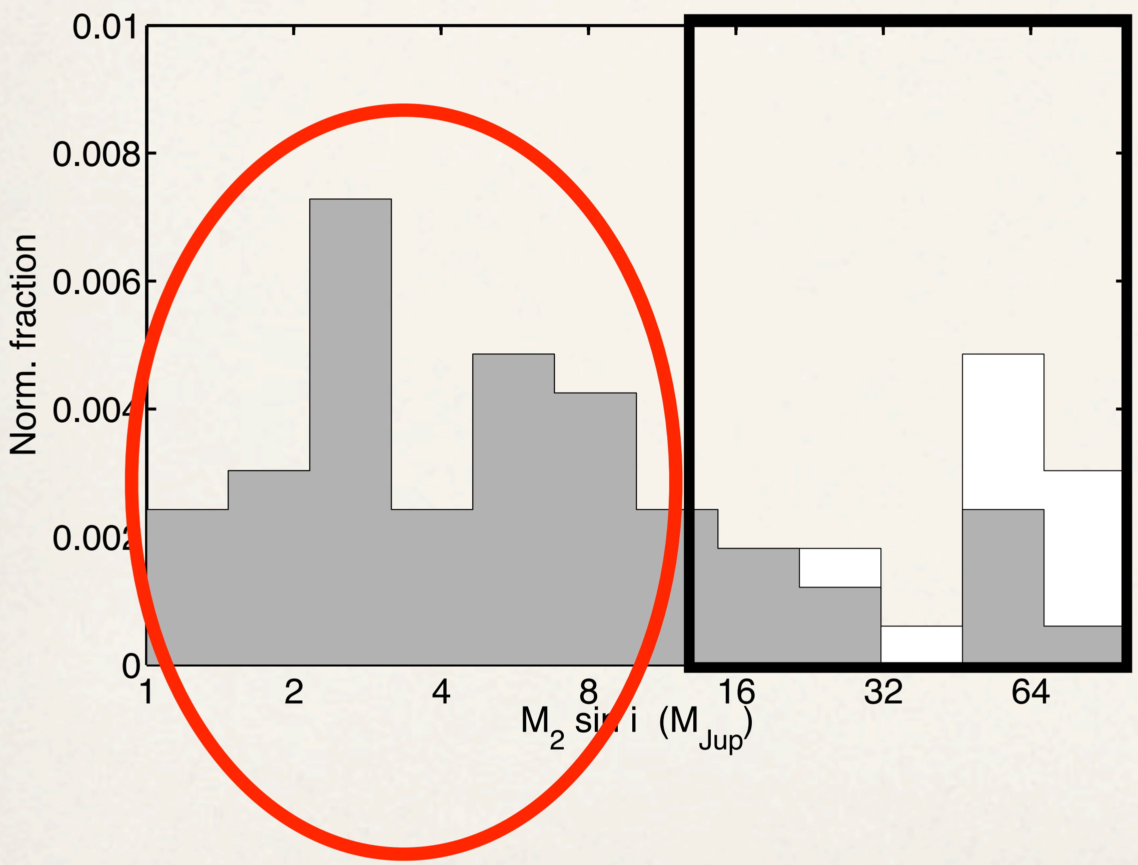
Sahlmann et al., 2011, A&A, 525

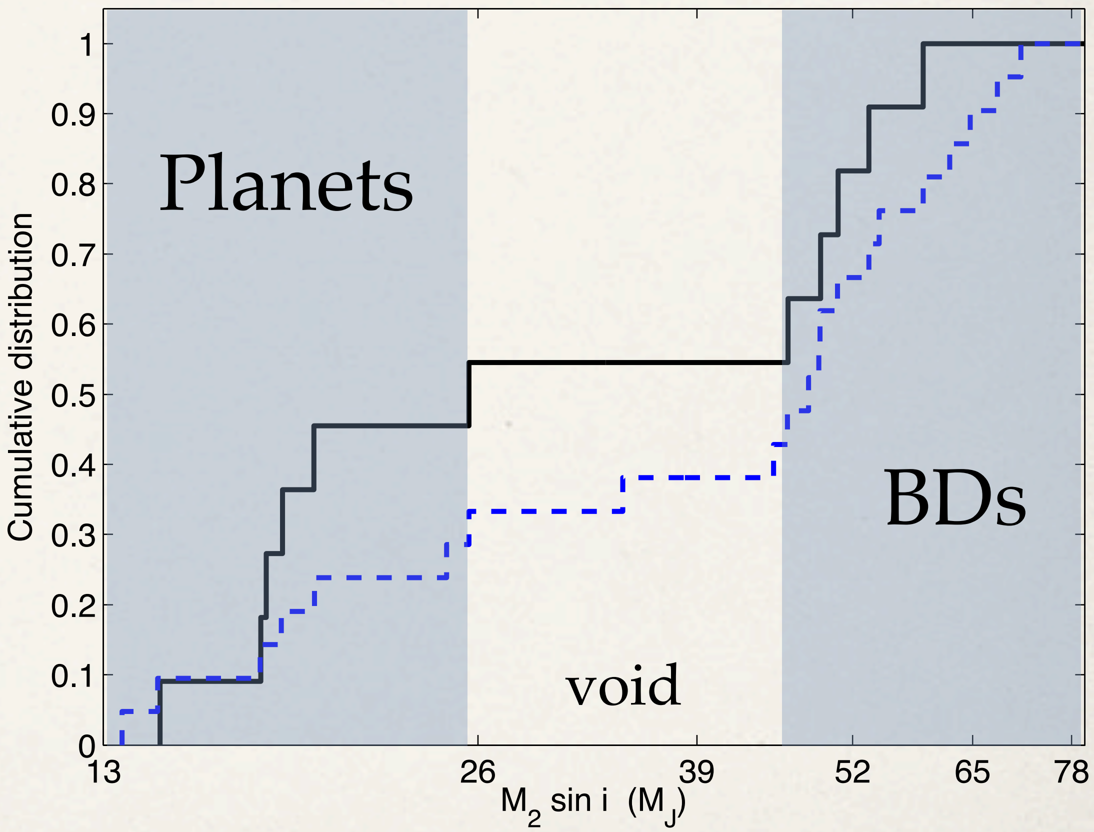
the upper mass limit for planets orbiting Sun-like stars revealed with astrometry

- RV: 20 candidate brown dwarf companions in uniform sample (CORALIE)
- Astrometry: 10 companions have true masses > 80 M_{Jup}, thus are M-dwarfs

⇒ 10 BD companions remain in the sample of 1647 stars.

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





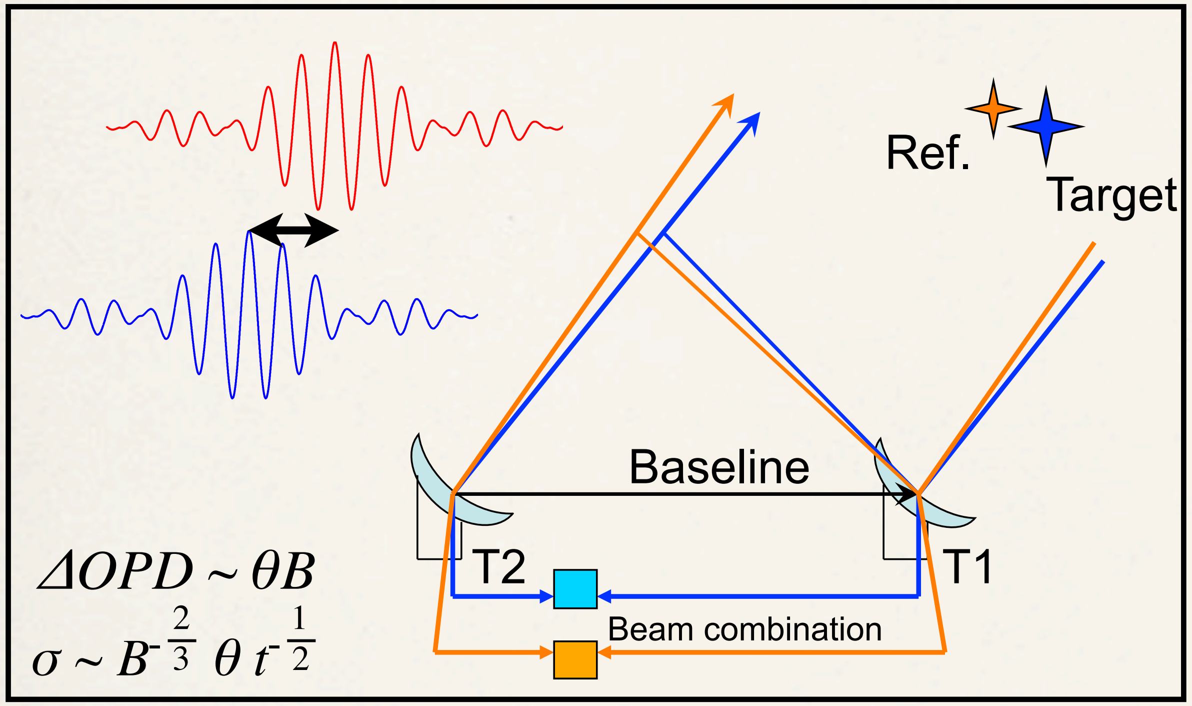
true masses?

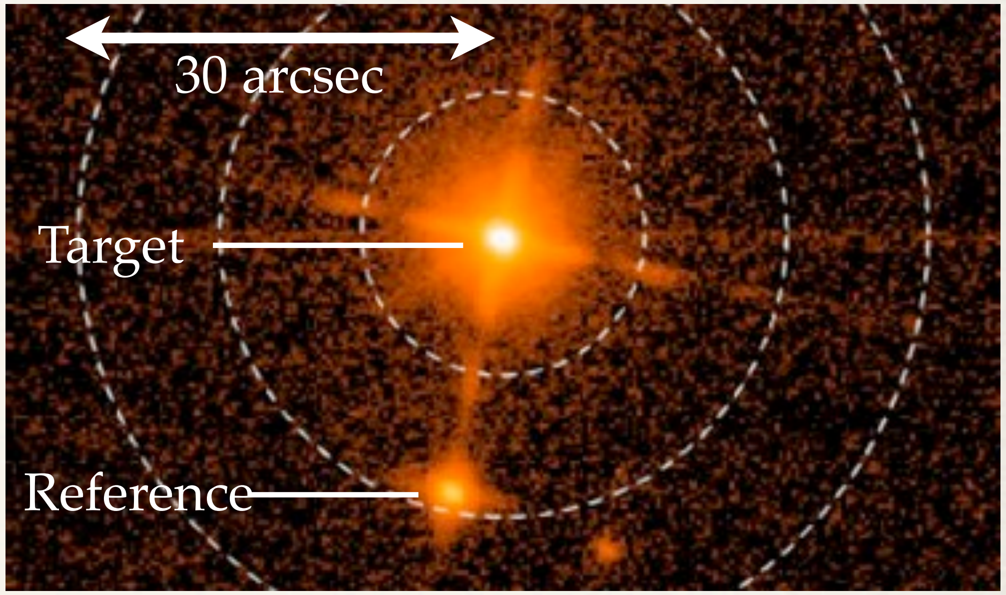
⇒ µas astrometry

⇒ upper planet mass limit at ~25-30 M_{Jup}

Sahlmann et al., 2011, A&A, 525 Sahlmann et al., 2011, IAUS 276

an IR-interferometer can realise 10 µas astrometry





K-band image of an ESPRI target.

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

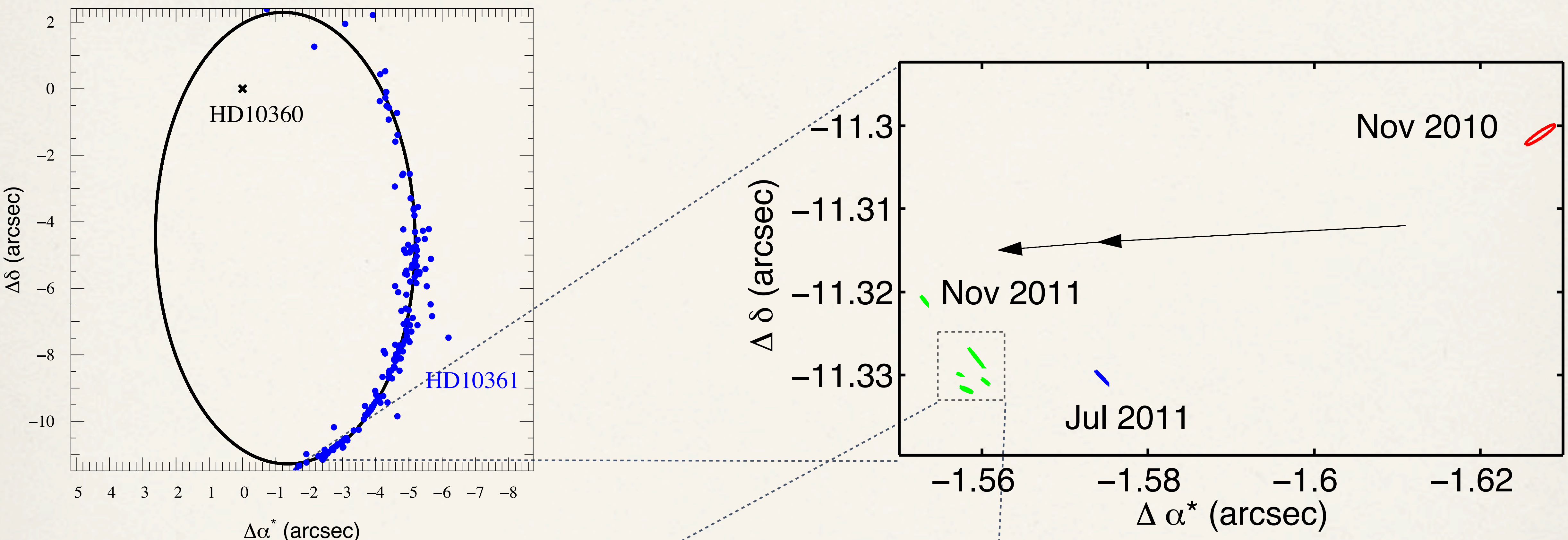
targets: hosts of RV planets, young stars, nearby main-sequence stars

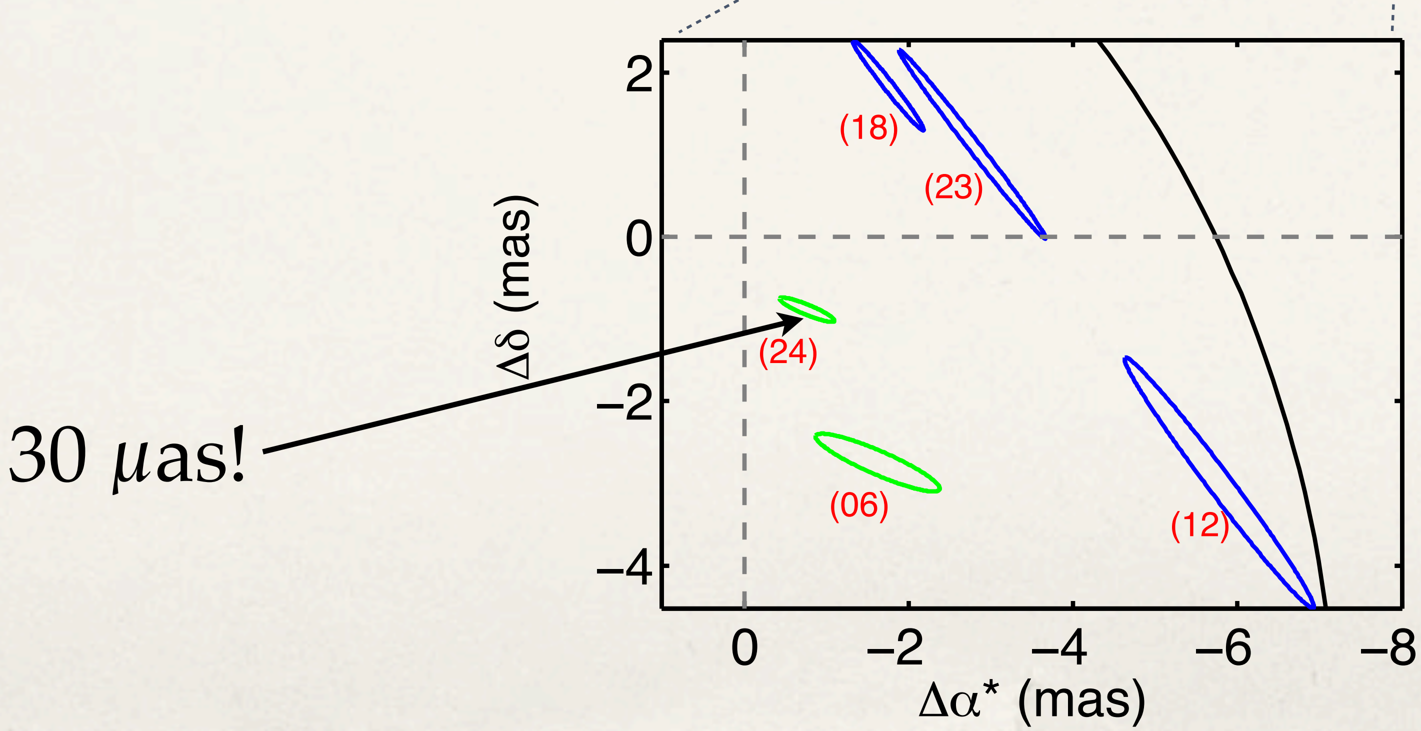
accuracy requirement: 10 - 100 μas

under commissioning at Paranal observatory

Launhardt et al., 2008

binary star observations with PRIMA





⇒ precision is sufficient

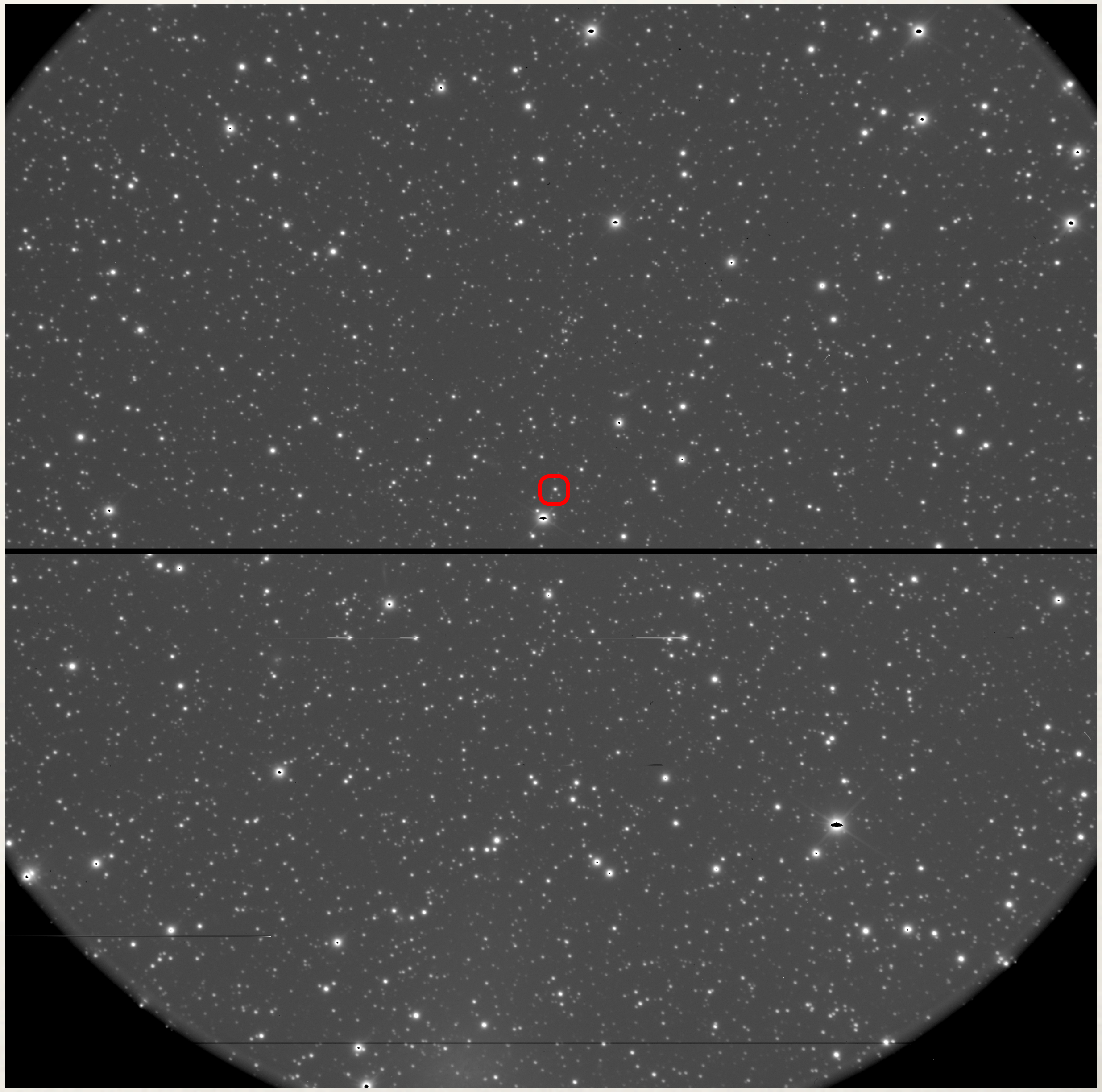
but biases are yet too large for the planet search

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

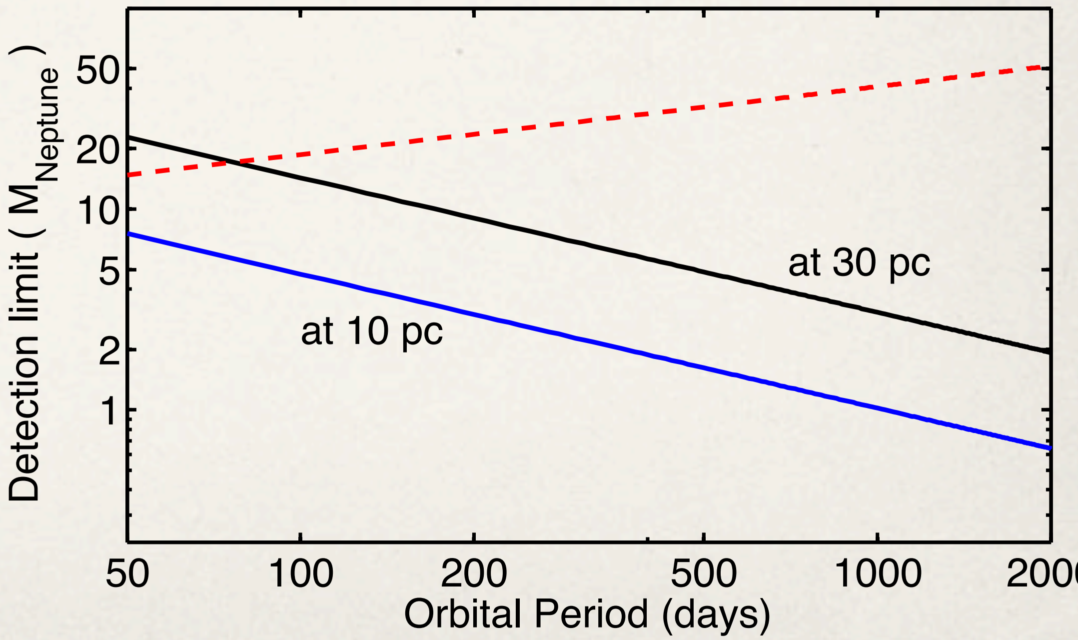
Performance Lazorenko et al. 2007, 2009, 2011

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

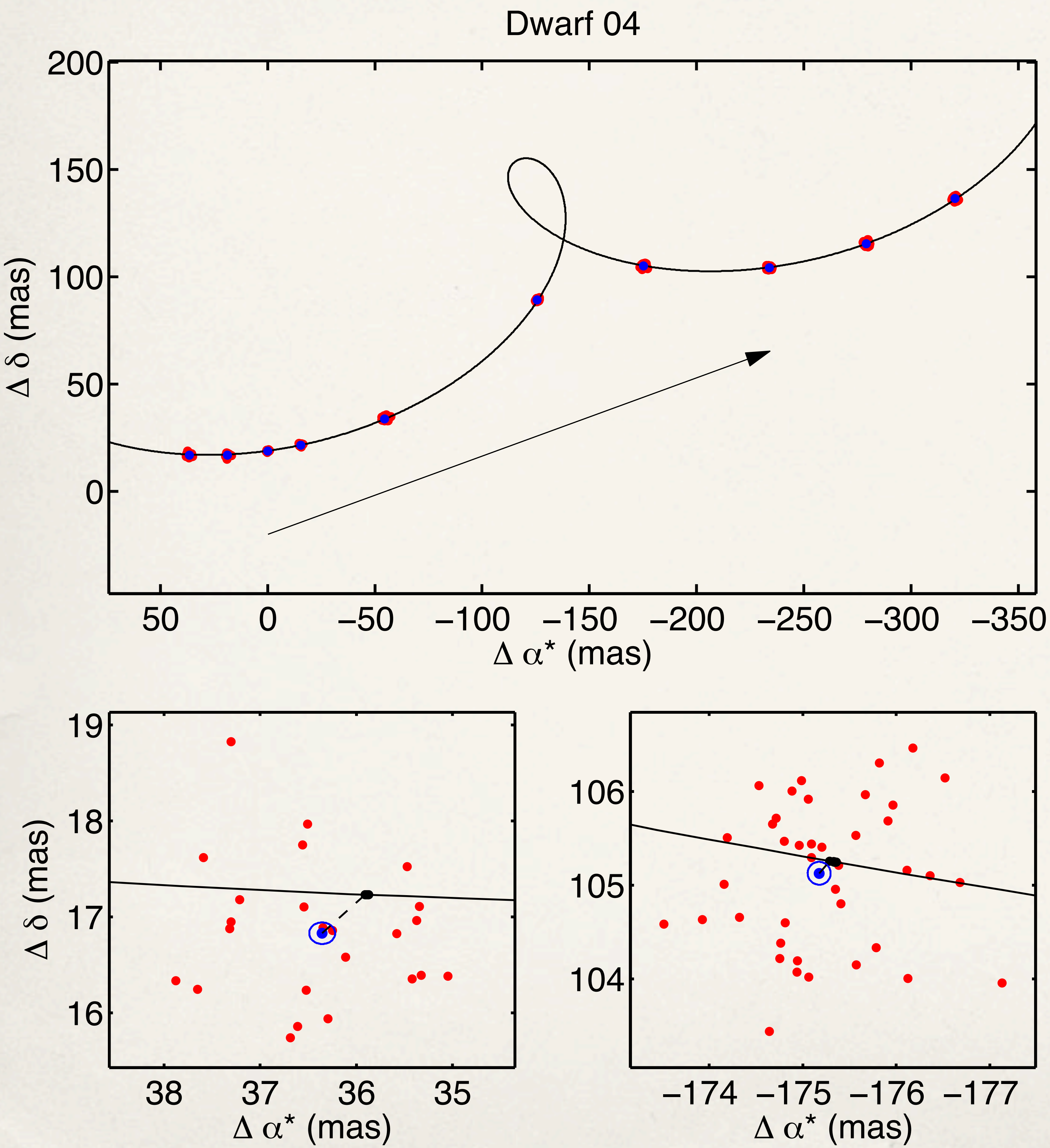
Planet search survey of 20 targets (ongoing)

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

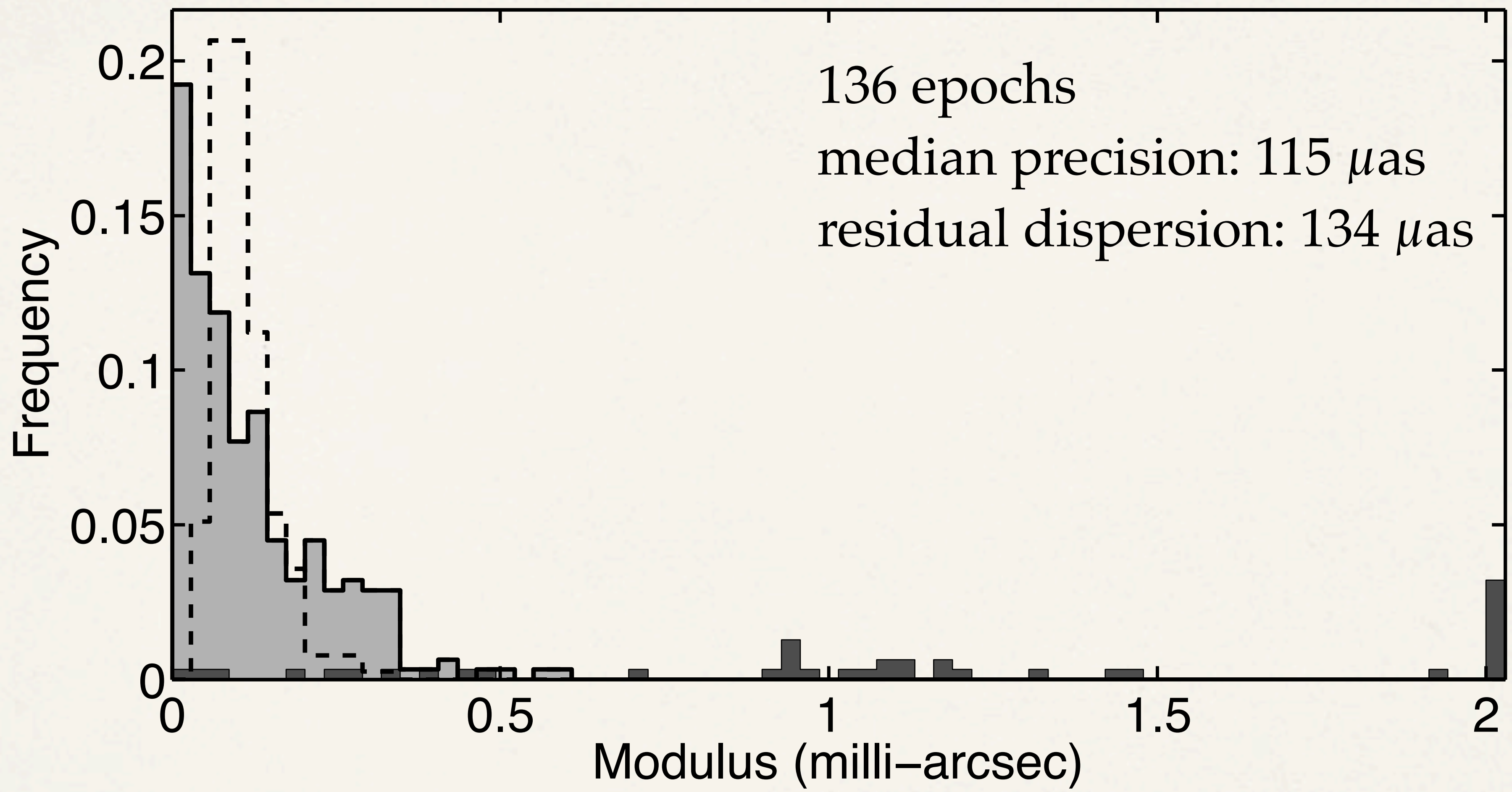


average epoch uncertainty: 110 μas

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

preliminary results



1. The long-term accuracy is < 130 μas per epoch. **Better than GAIA for faint targets!**

2. Exclude planets more massive than Jupiter in intermediate periods (~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