Astrometric planet search around southern ultracool dwarfs

Johannes Sahlmann
ESA Research Fellow

P.F. Lazorenko (MAO Kiev)
E.L. Martín (CAB Madrid)
D. Ségransan (Obs Geneva)
M. Mayor (Obs Geneva)
D. Queloz (Obs Geneva)
S. Udry (Obs Geneva)

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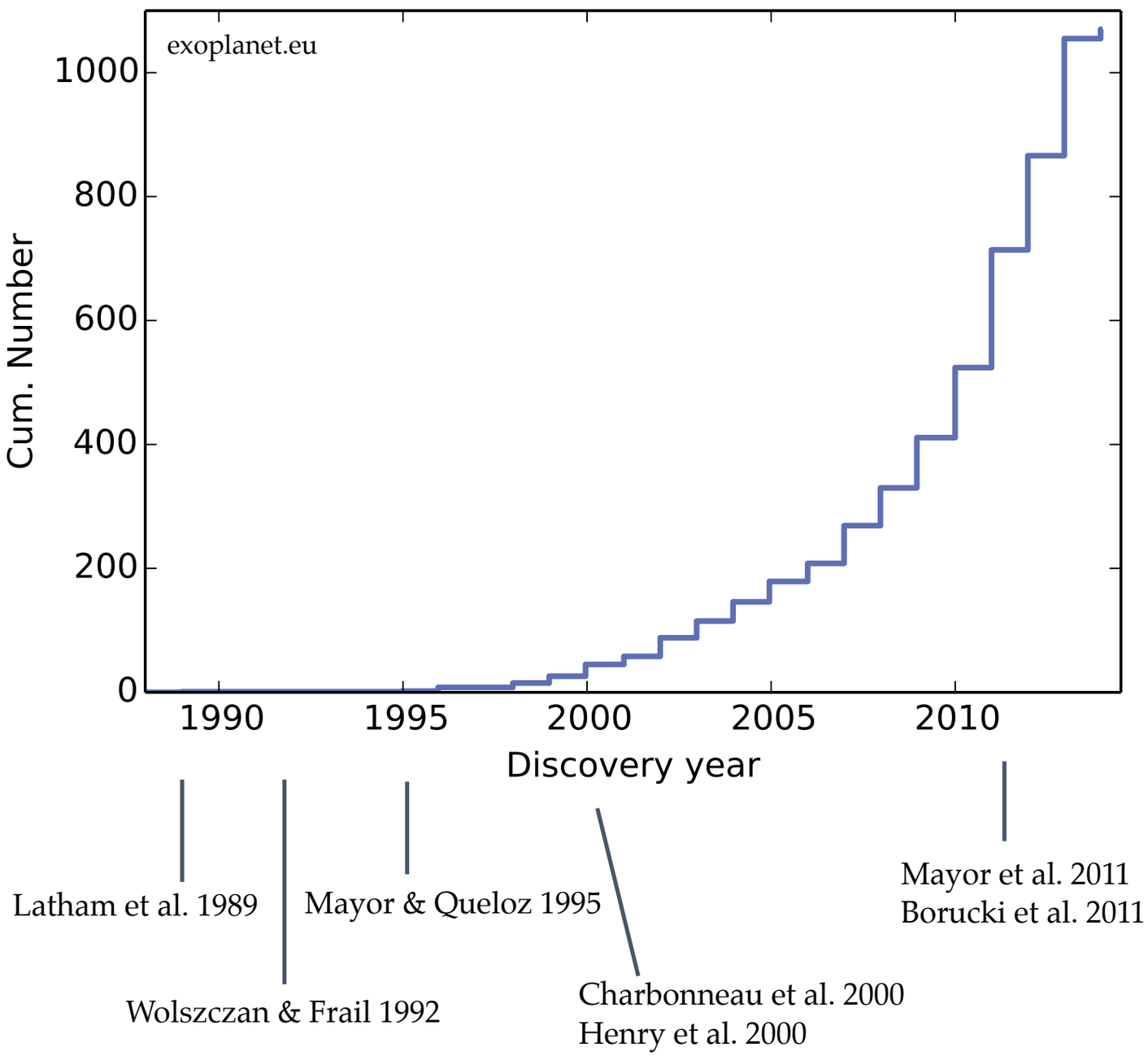
EXOPLANETS ARE ABUNDANT AND DIVERSE



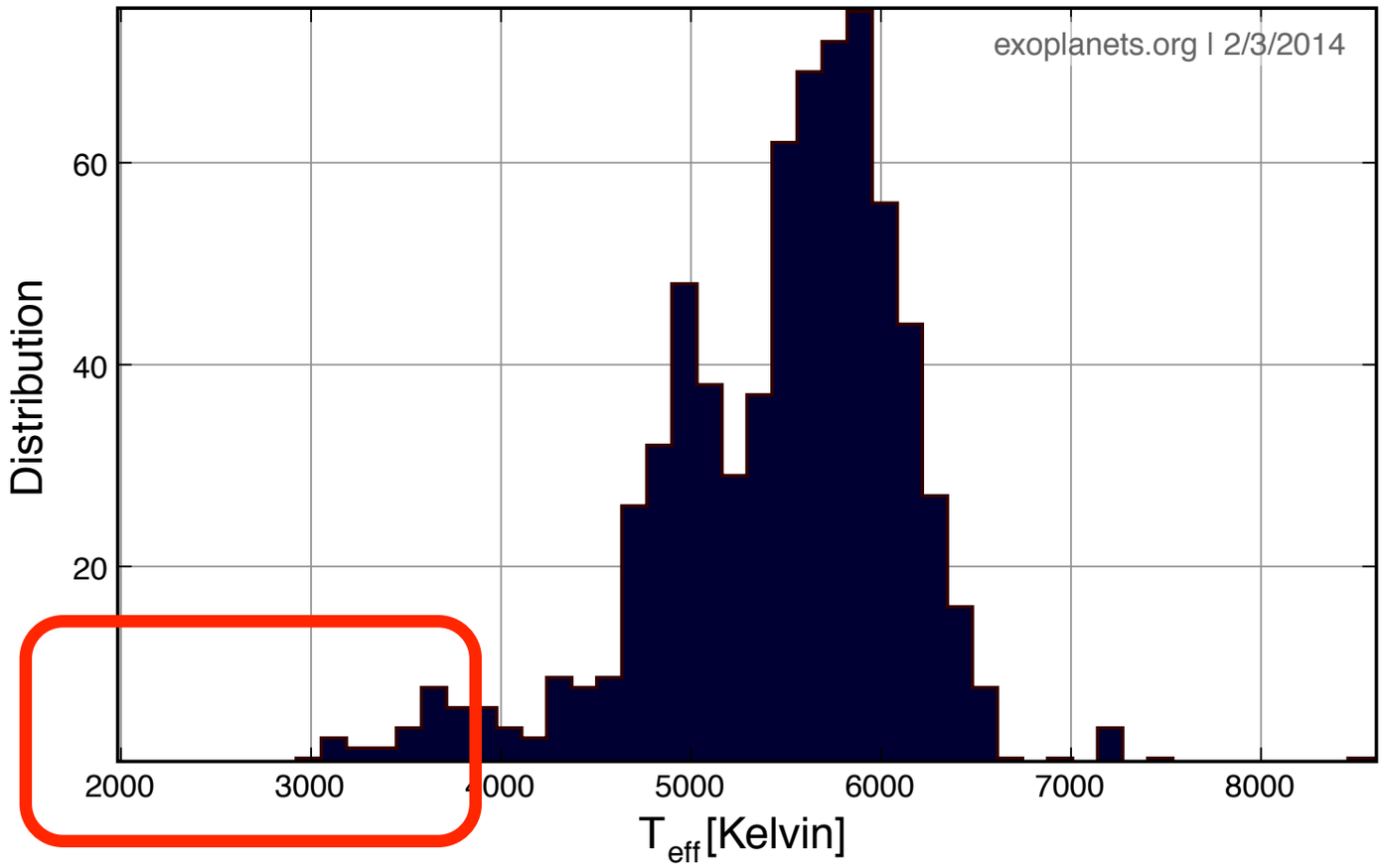
HARPS-S:
75 ± 7 % of Sun-like stars host a planet (Mayor et al. 2011)

Kepler:
~3800 planet candidates

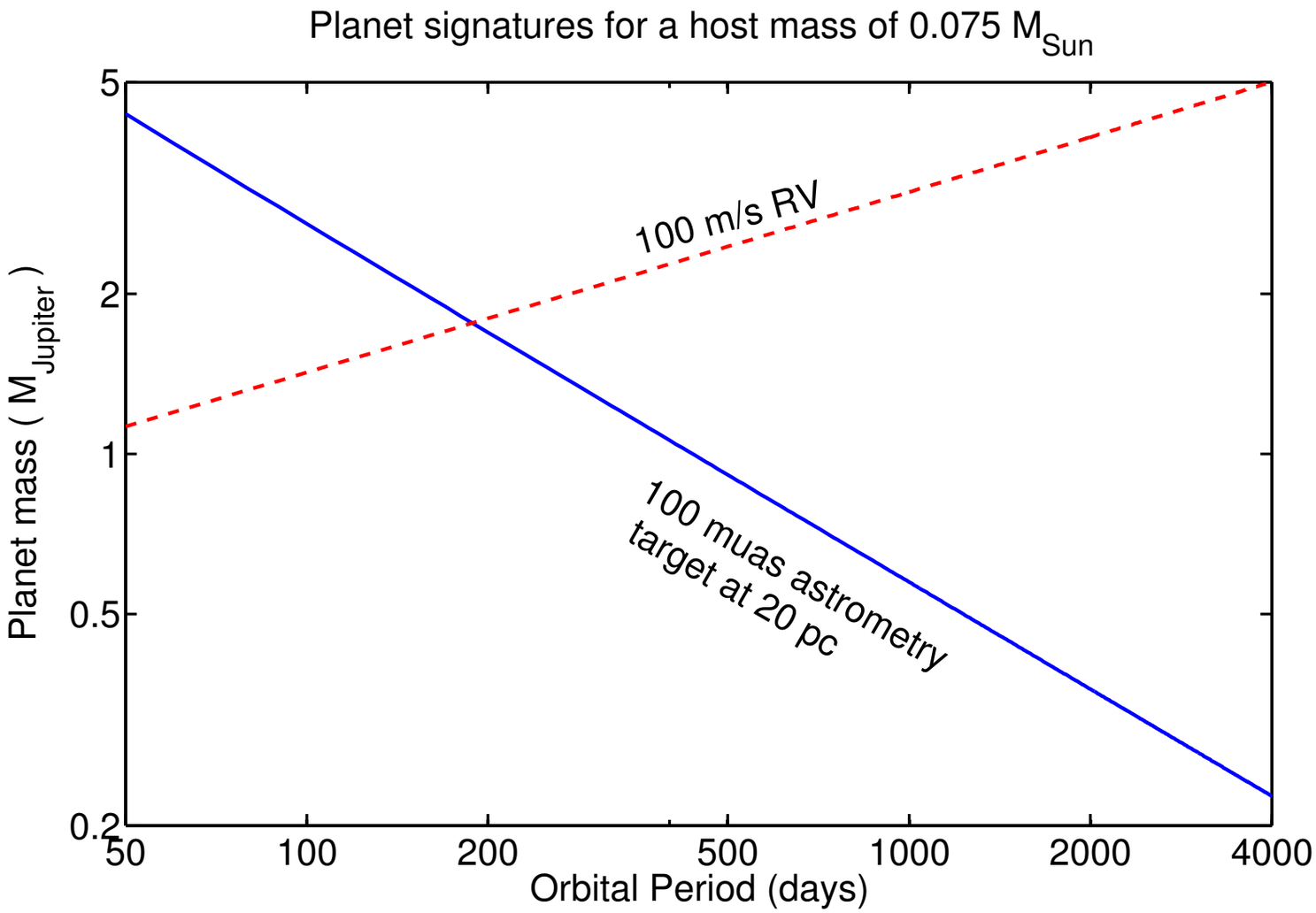
Microlensing statistics

WE SEARCH FOR PLANETS AROUND OBJECTS AT THE STELLAR/SUBSTELLAR BOUNDARY

Are the conditions for planet formation met around ultracool dwarfs?



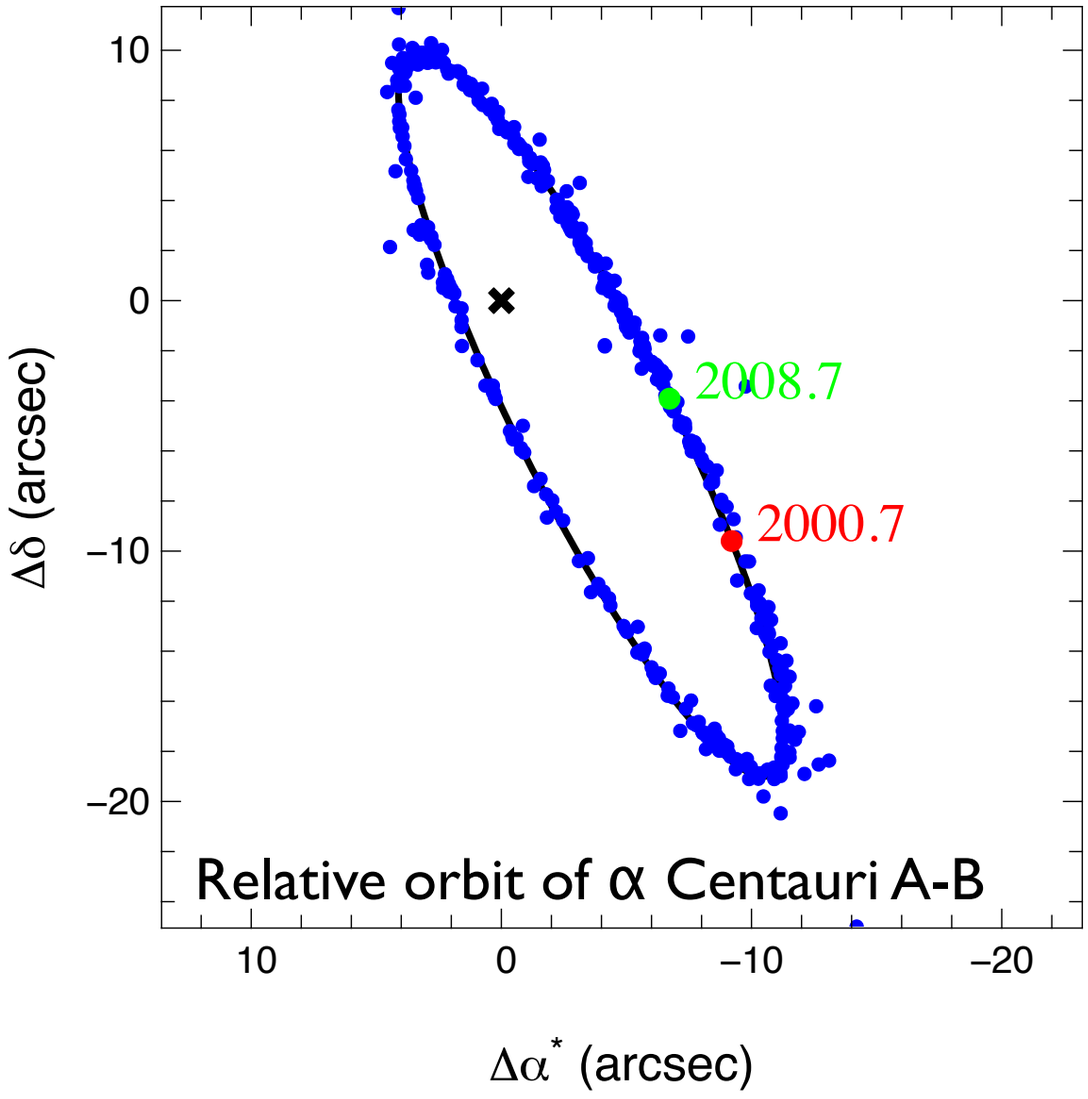
ASTROMETRY OPENS UP A UNIQUE DISCOVERY SPACE



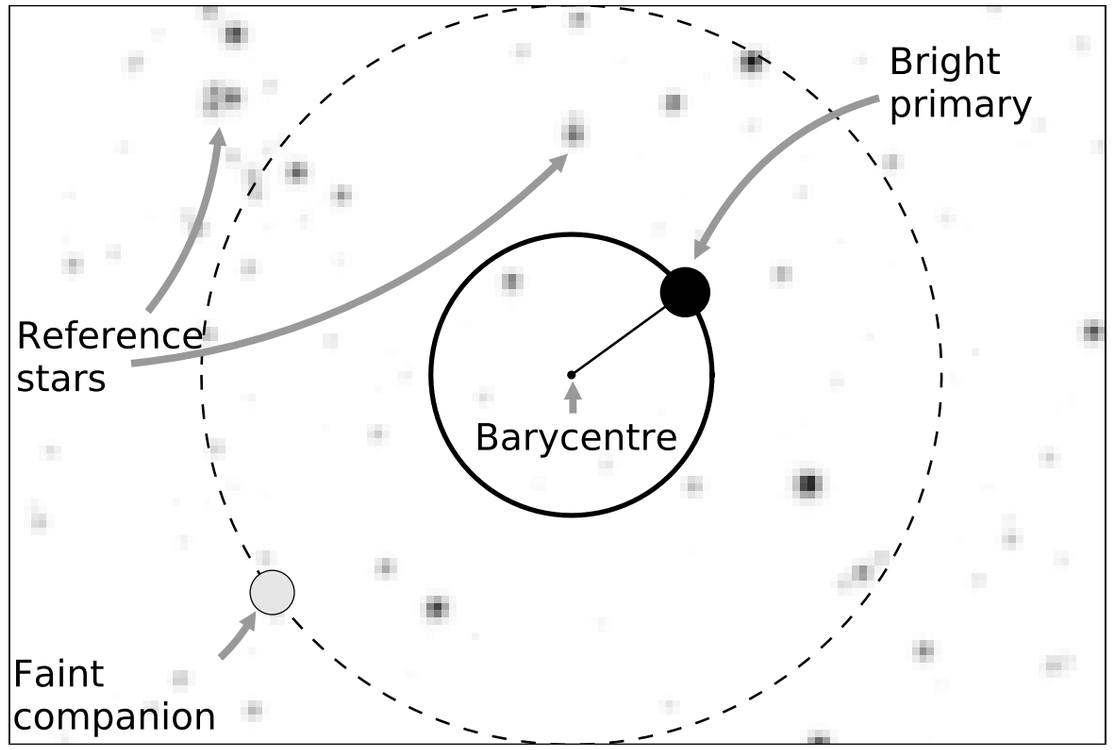
Astrometry:
- detectability does not depend on orbit orientation
- not limited to slow rotators
- optimal for intermediate period planets
- distance dependent

RELATIVE ORBIT > BARYCENTRIC ORBIT

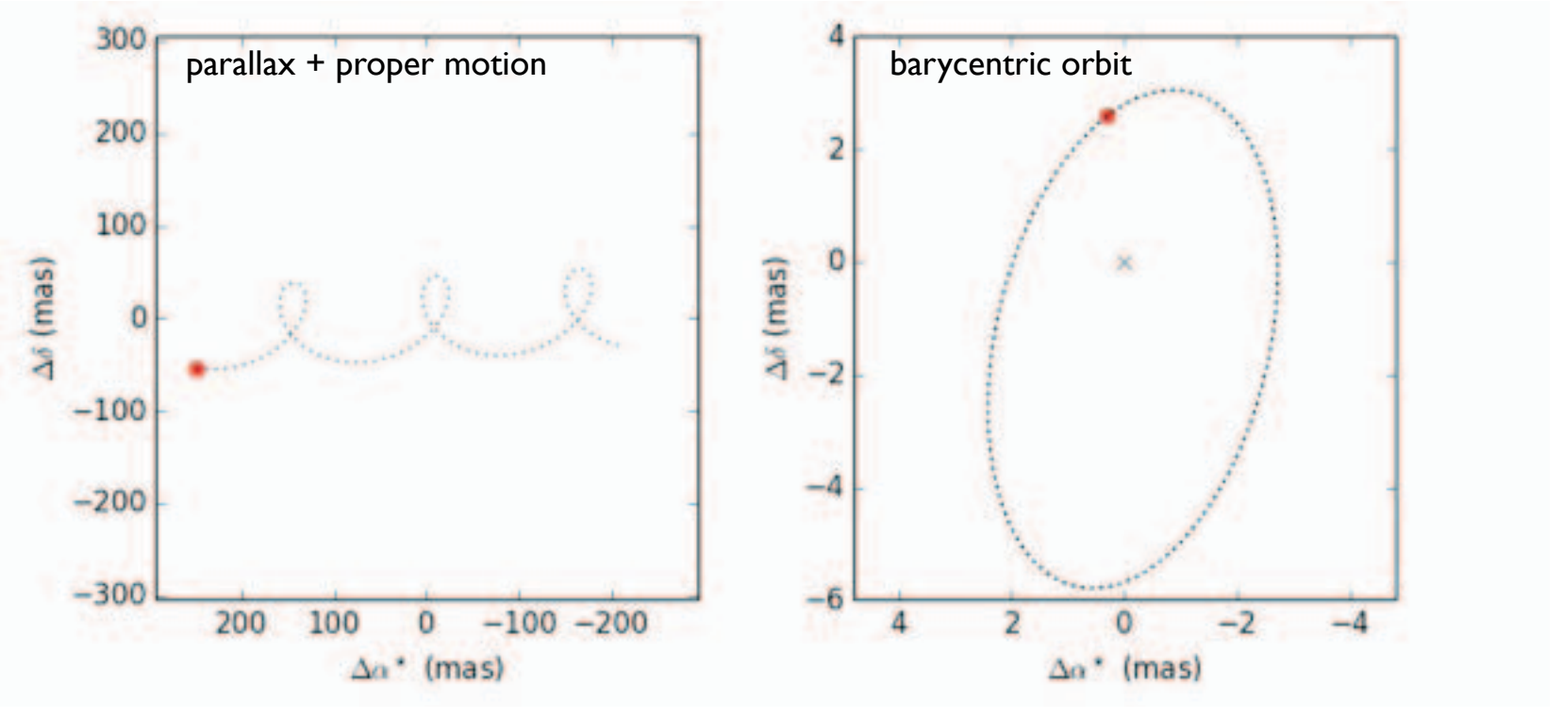
Visual binary

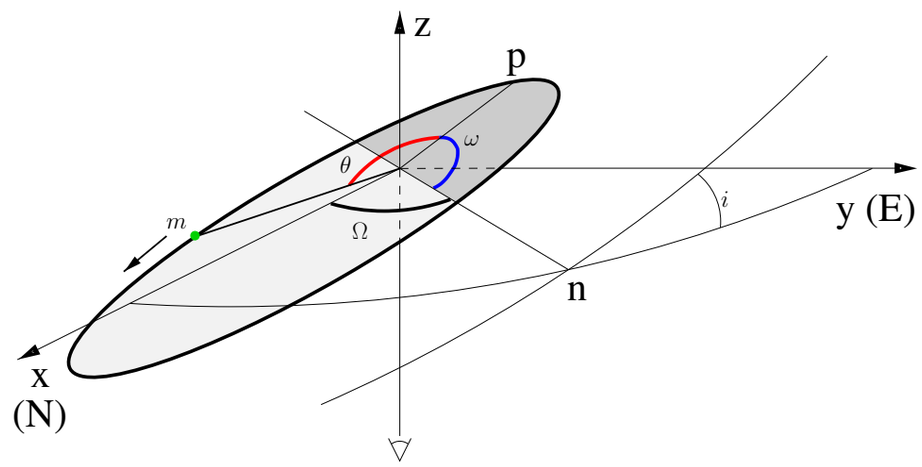


Exoplanet host star



12 PARAMETERS DESCRIBE AN ASTROMETRIC ORBIT





Sahlmann, 2012, PhD thesis

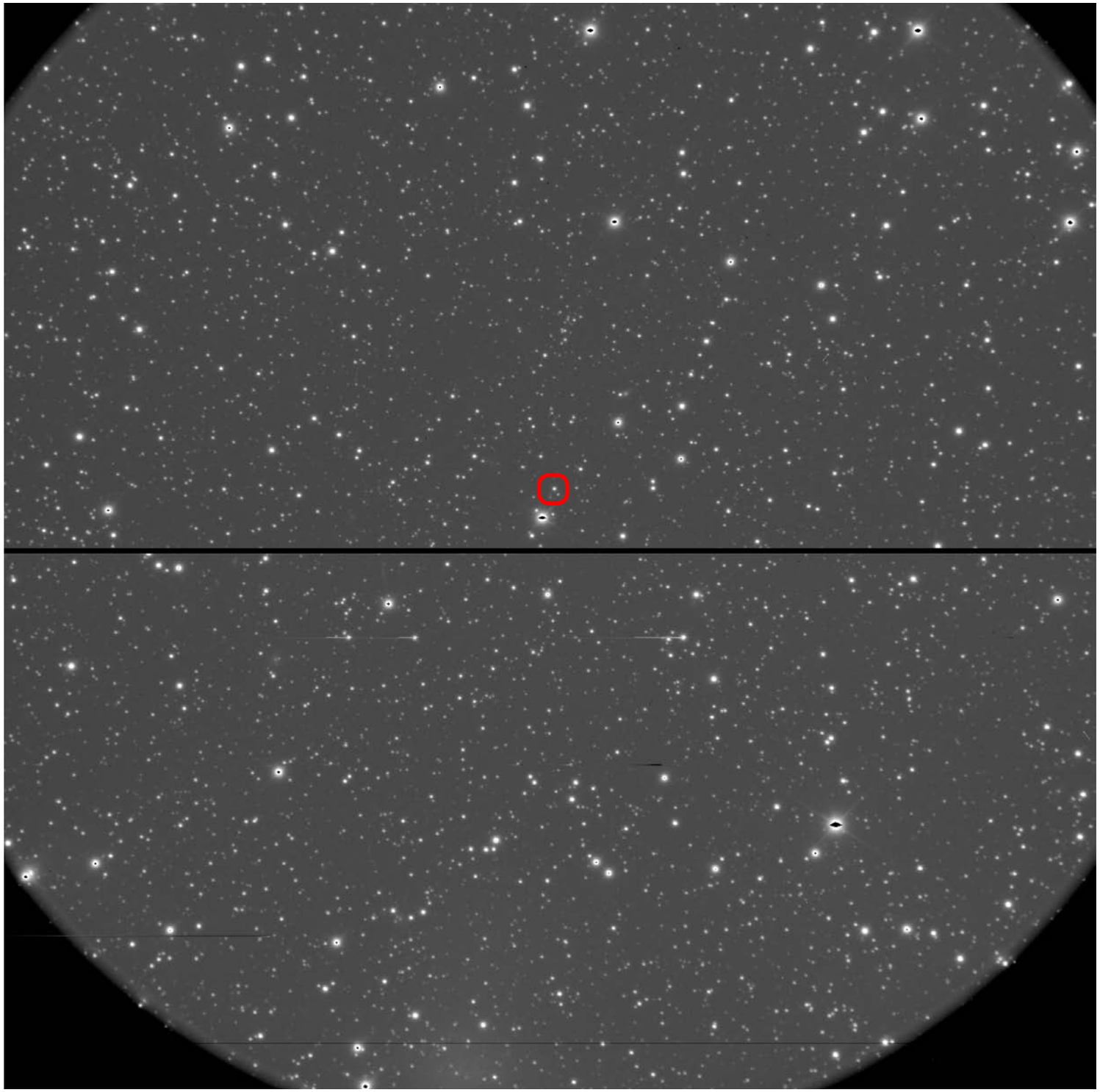
5 standard astrometric parameters:

2 positions + parallax +
2 proper motions

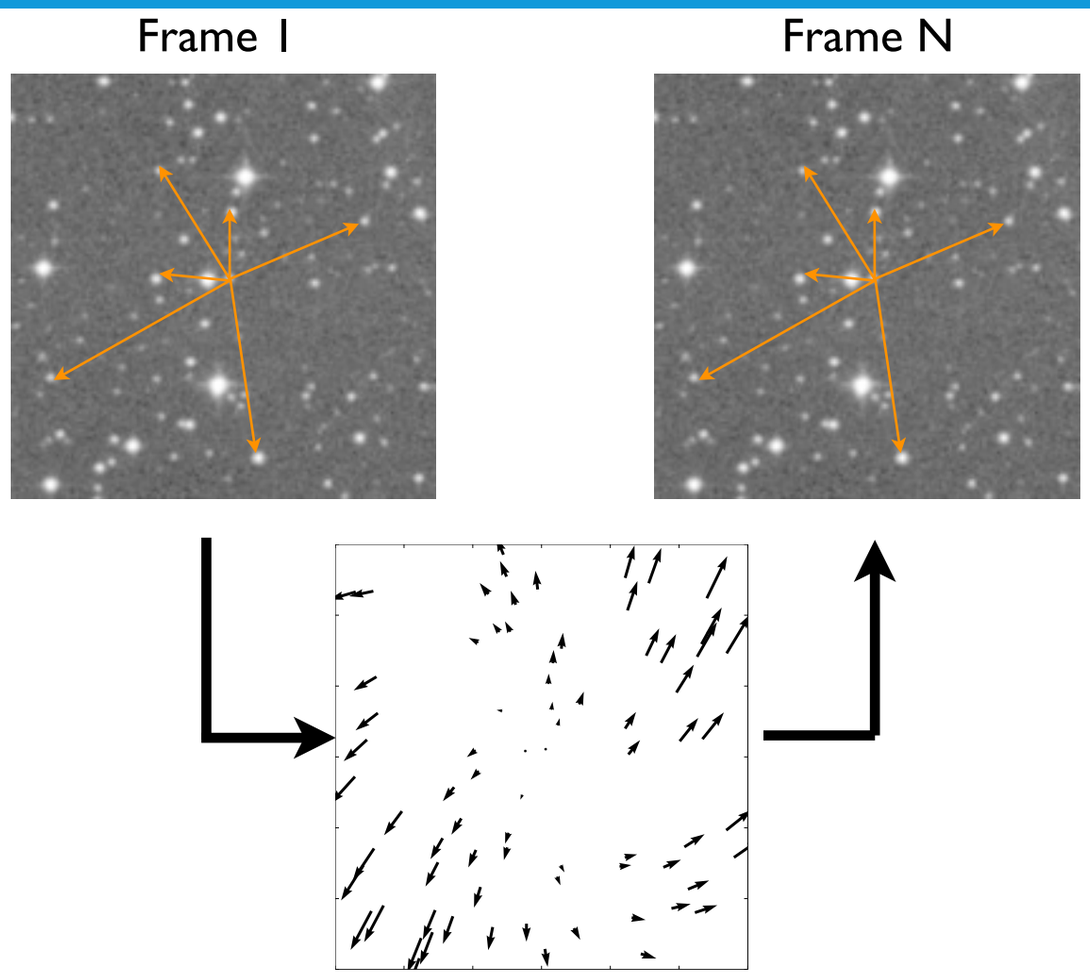
7 orbit parameters:

Period, semi-major axis, eccentricity,
inclination + angles (P, a, e, i, Ω, ω, Φ_0)

SEARCH FOR PLANETS AROUND ULTRA-COOL DWARFS



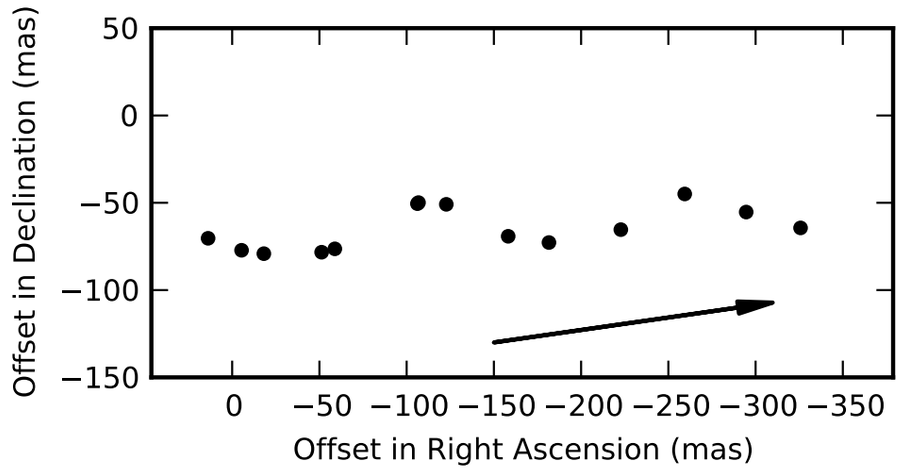
ASTROMETRY WITH IMAGES



Extract relative position of the target in every frame

Map the field of reference stars from frame to frame

Obtain time series of relative astrometry



Ground: Narrow-field atmospheric limit with D ~10 m is **10-100 µas**

(seeing limited or AO corrected, reasonable integration times)

see Lindegren 1978, Lazorenko & Lazorenko 2004, Lazorenko et al. 2009, Cameron et al. 2009, Fritz et al. 2010

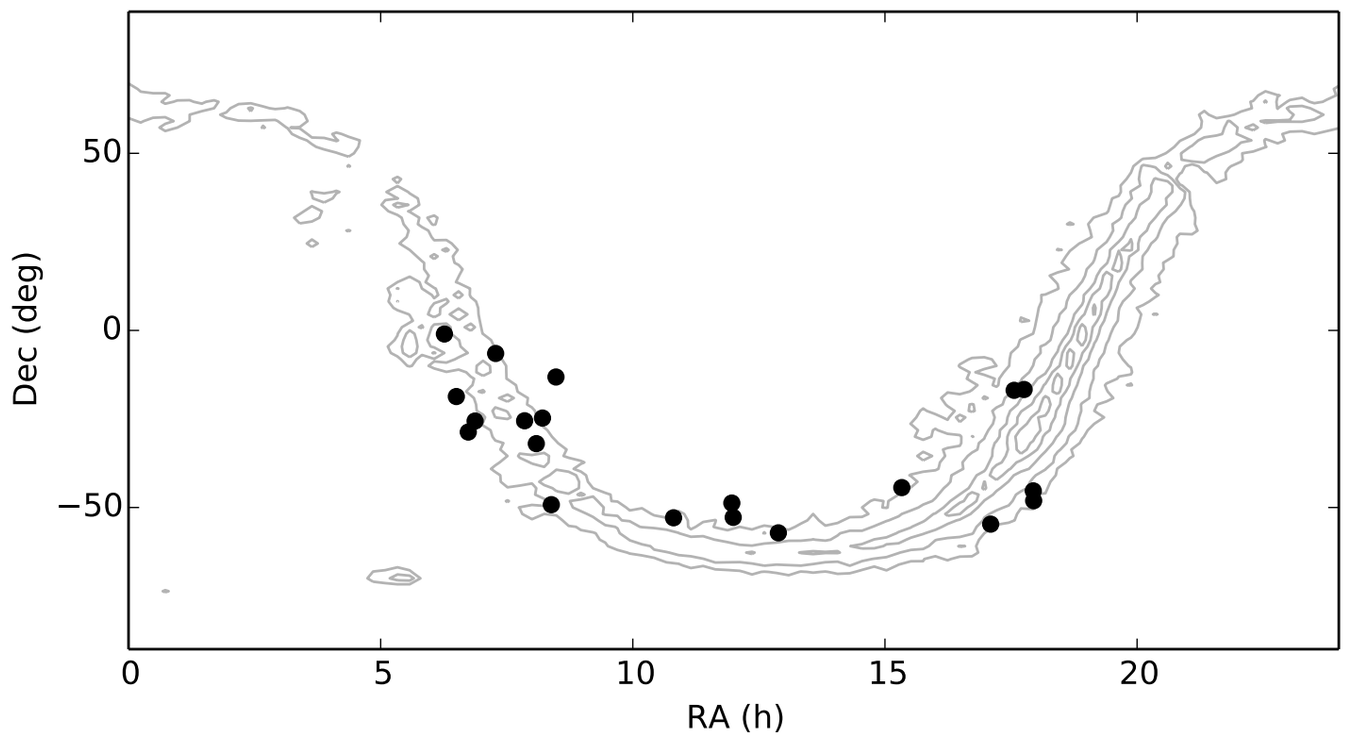
PALTA: PLANETS AROUND M/L DWARFS WITH ASTROMETRY

FORS2 camera at the Very Large Telescope demonstrated an astrometric performance of 50-100 μas (Lazorenko, Sahlmann, et al. 2011)

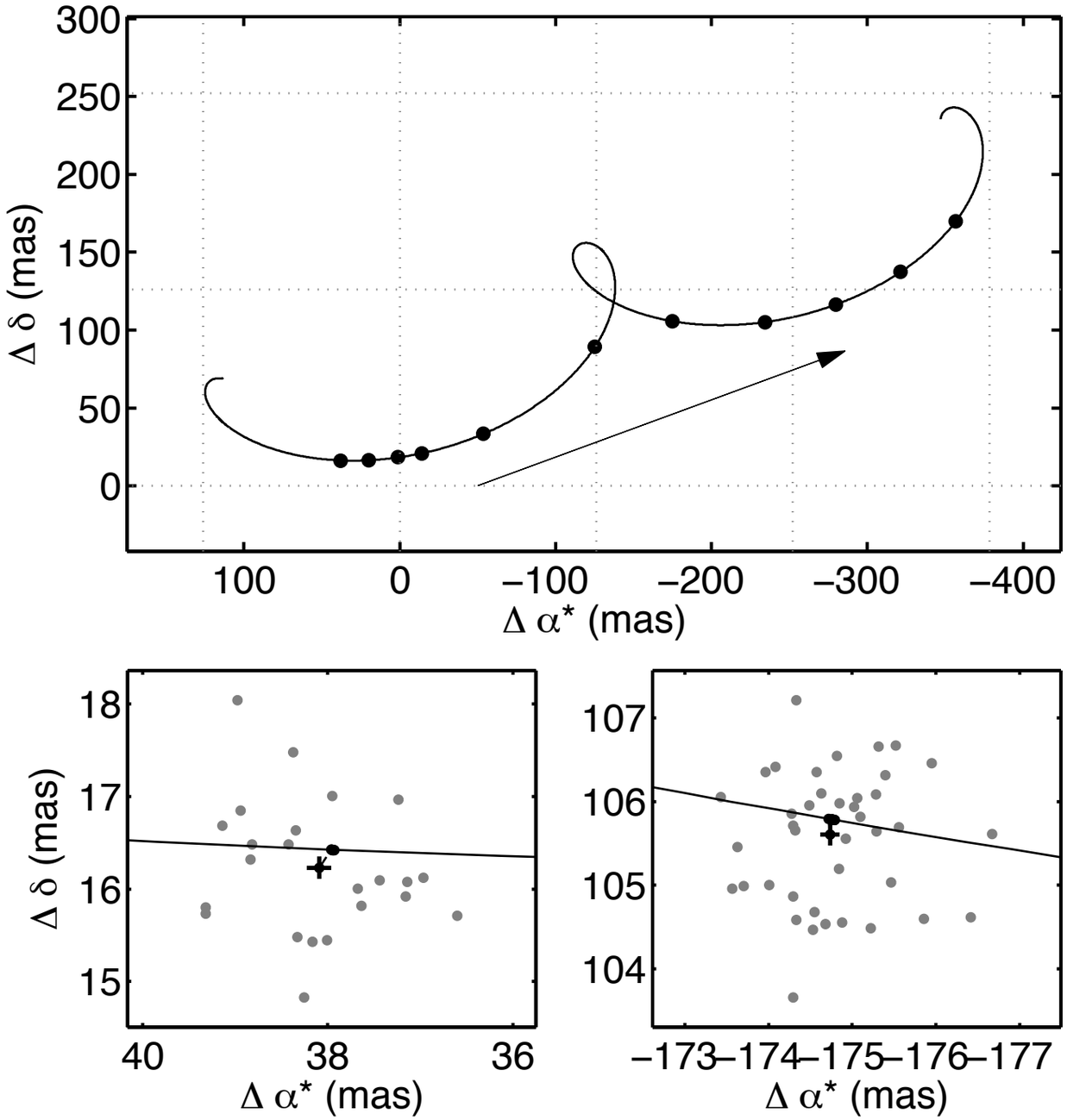
Detection limit: 3 x Neptune-mass planet in 700 day orbit around 0.08 M_{Sun} primary.

→ NEW DISCOVERY SPACE

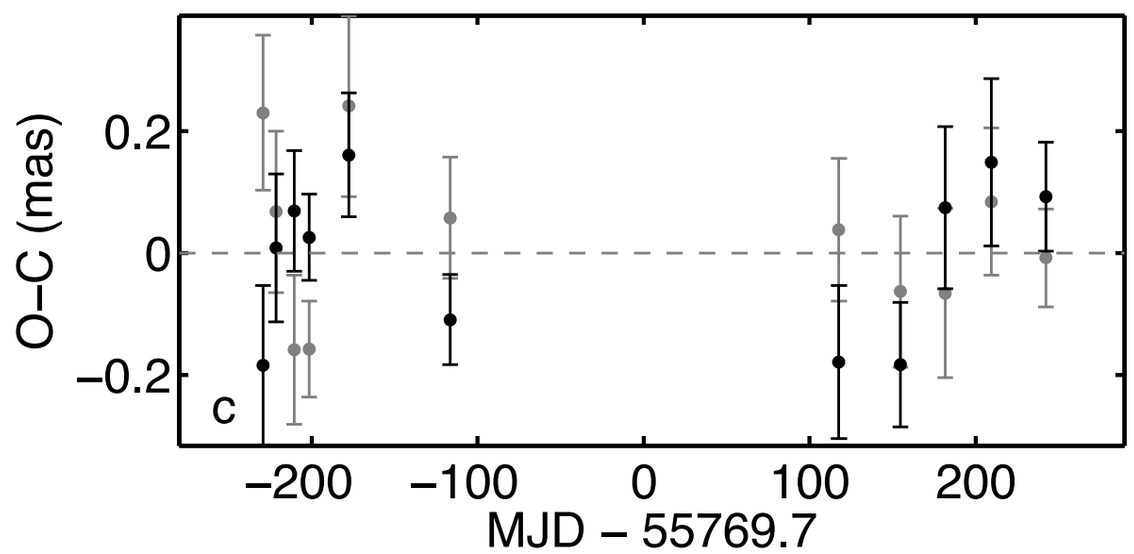
Started monitoring 20 nearby late-M and early-L dwarfs close to the Galactic plane in 2010.



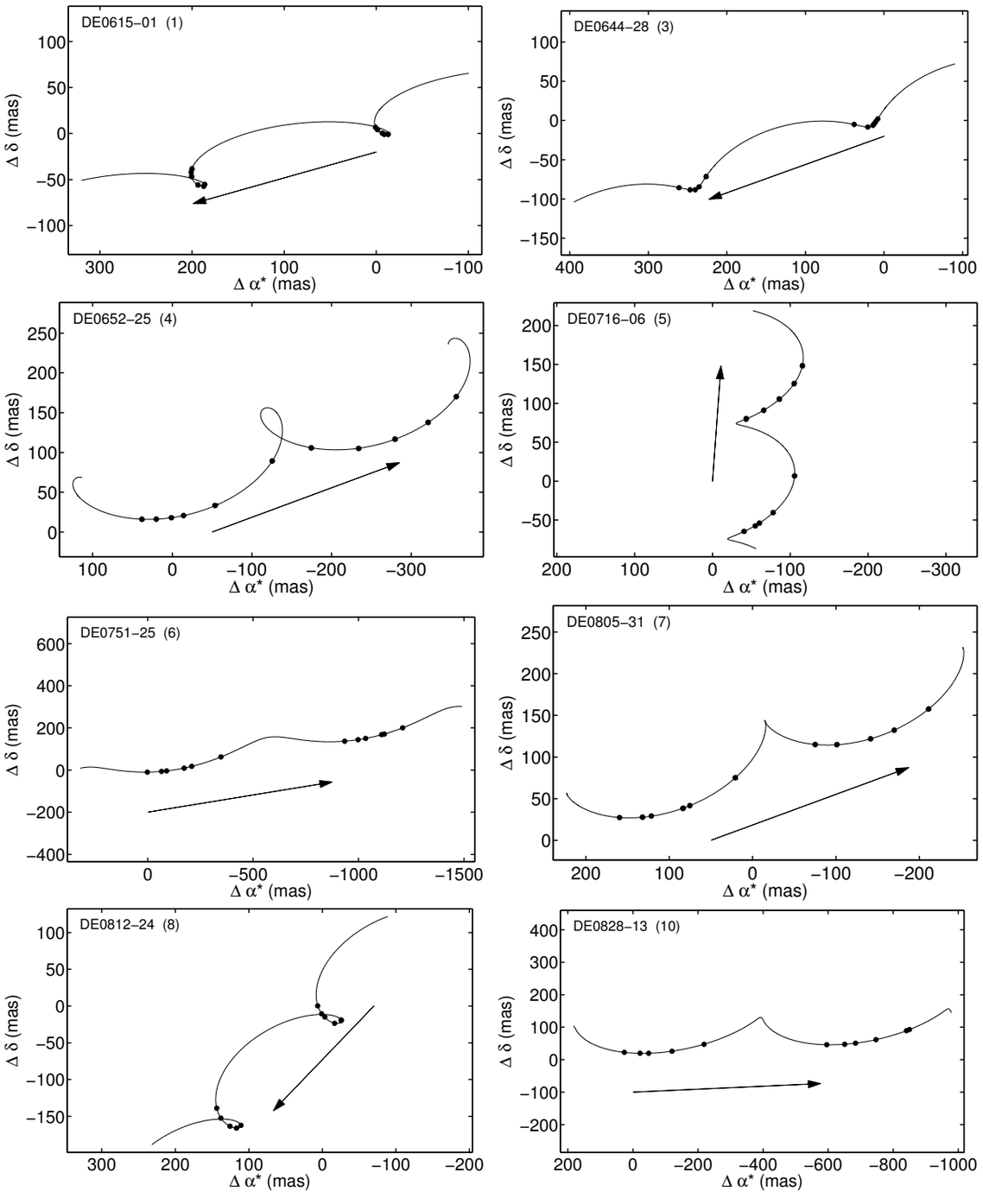
MEASURING PARALLAX AND PROPER MOTION

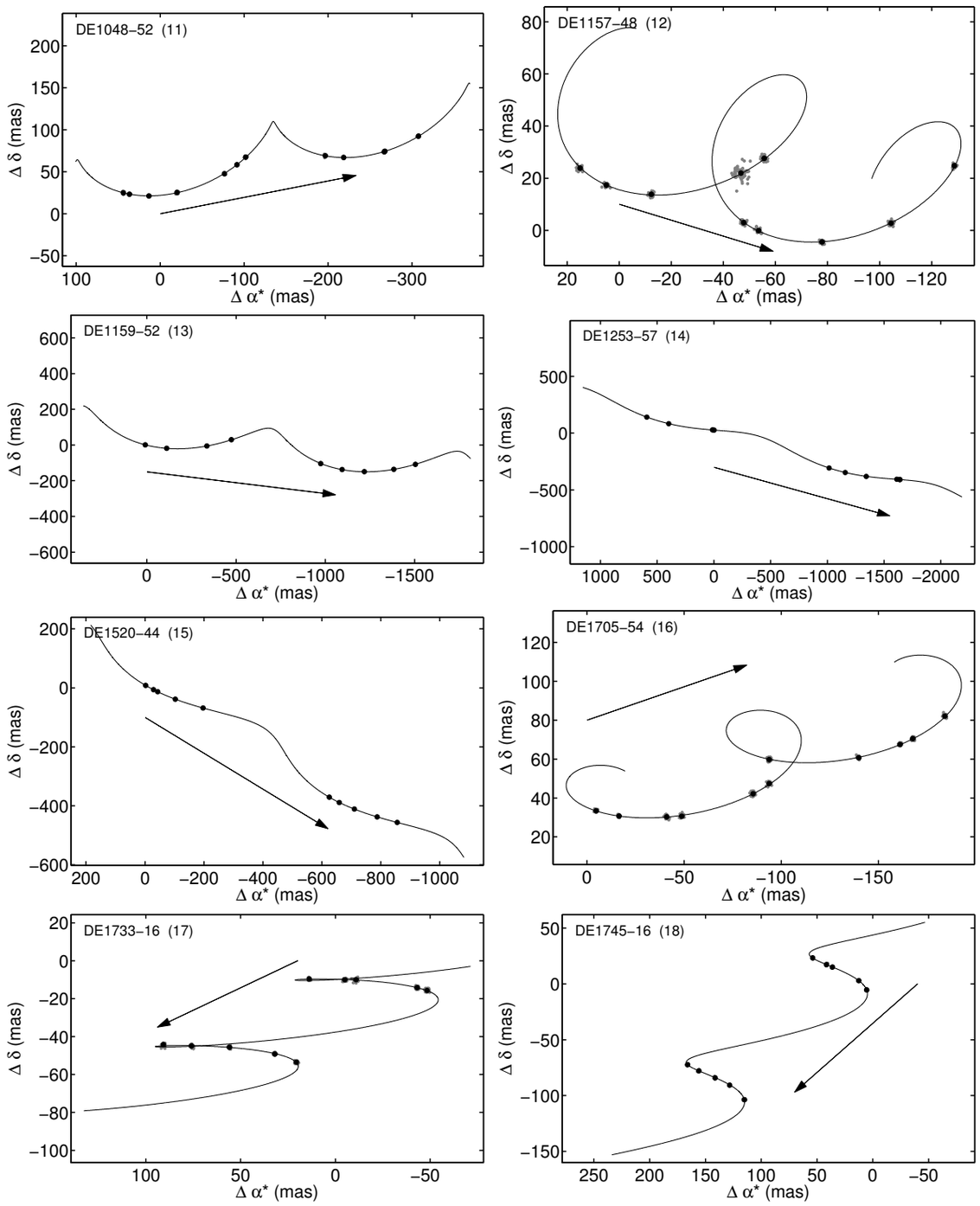


average epoch uncertainty: 120 µas
residual dispersion: 140 µas
Relative parameters:
parallax 60.87 +/- 0.06 mas
proper motion RA -234.31 +/- 0.09 mas/yr
proper motion DE 85.48 +/- 0.07 mas/yr

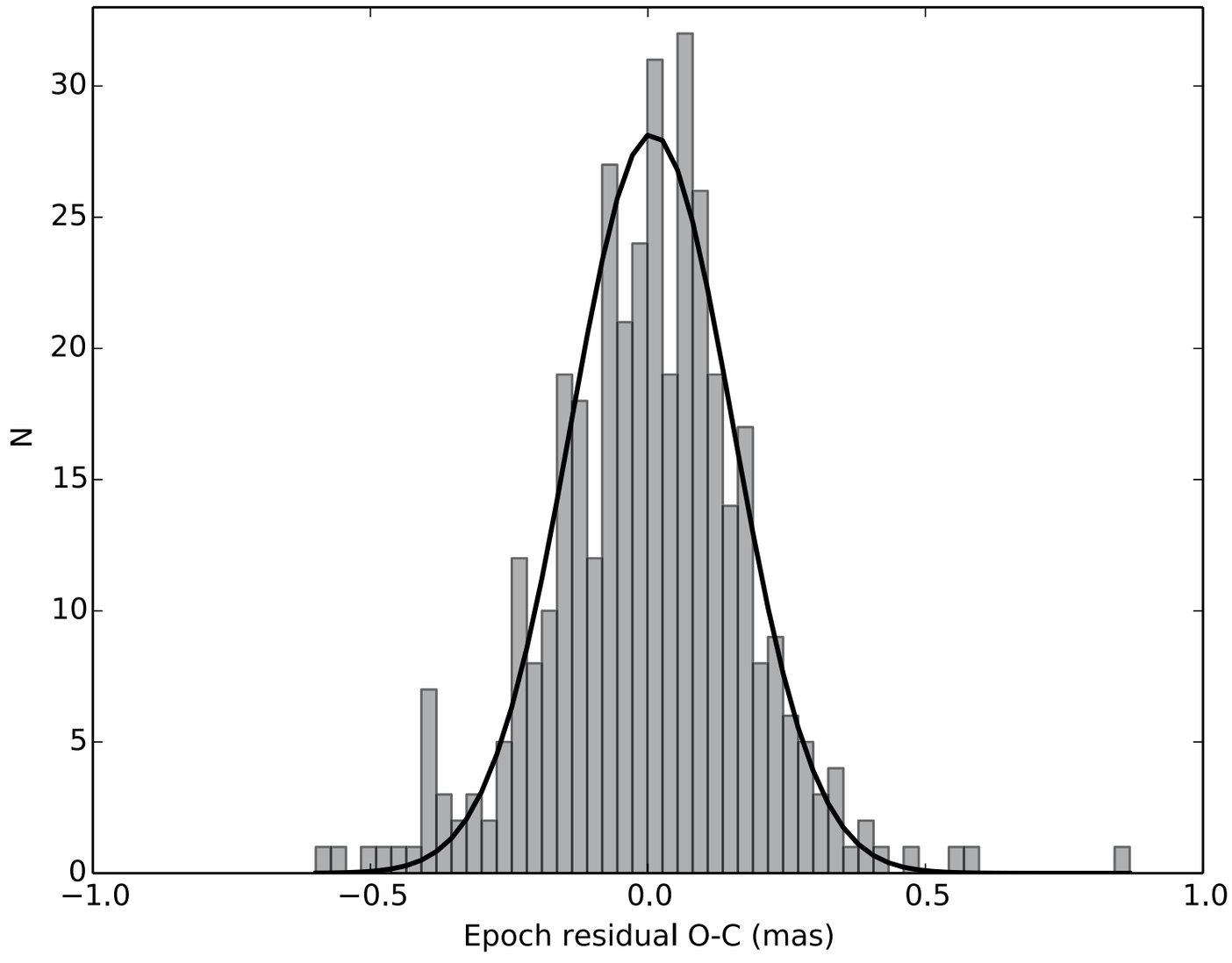


A GALLERY OF ULTRACOOL DWARF MOTIONS





100 MICRO-ARCSEC ASTROMETRY IS POSSIBLE FROM THE GROUND



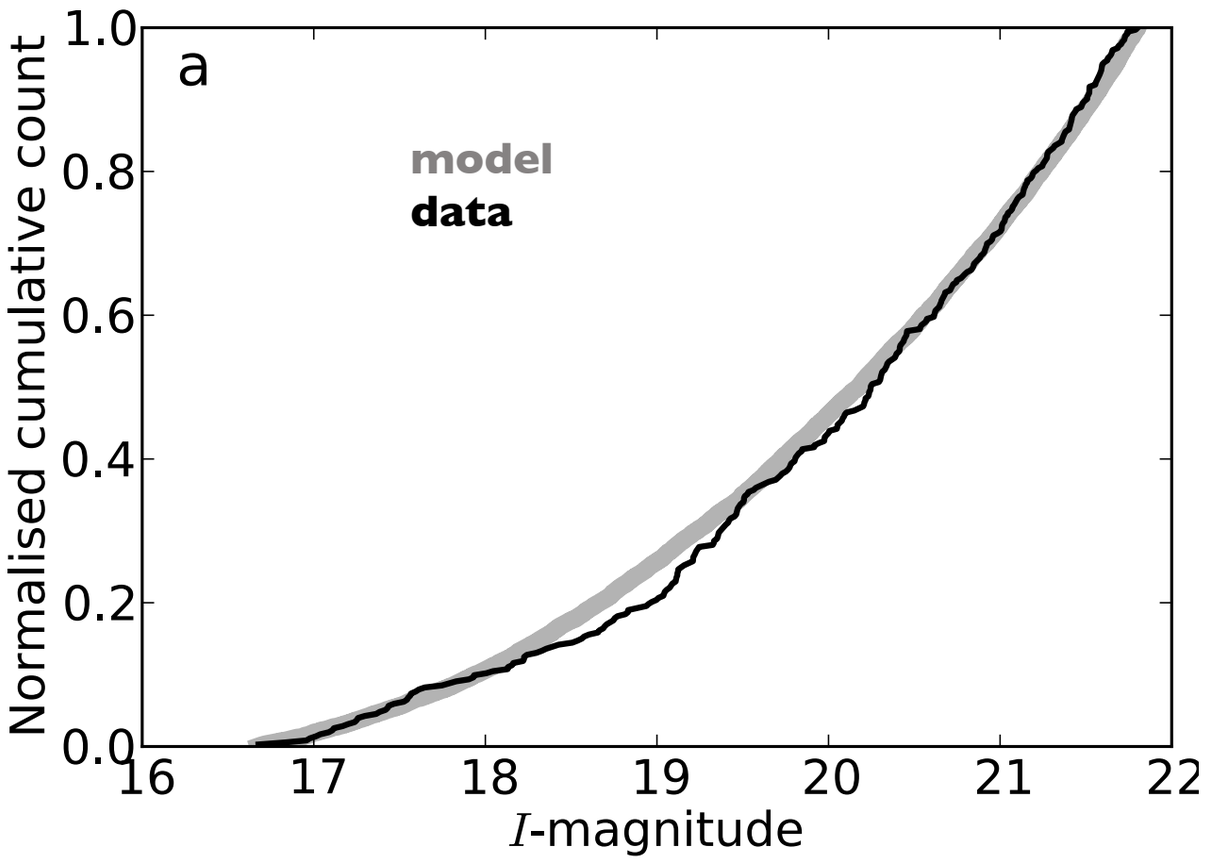
18 objects
180 epochs
24 months

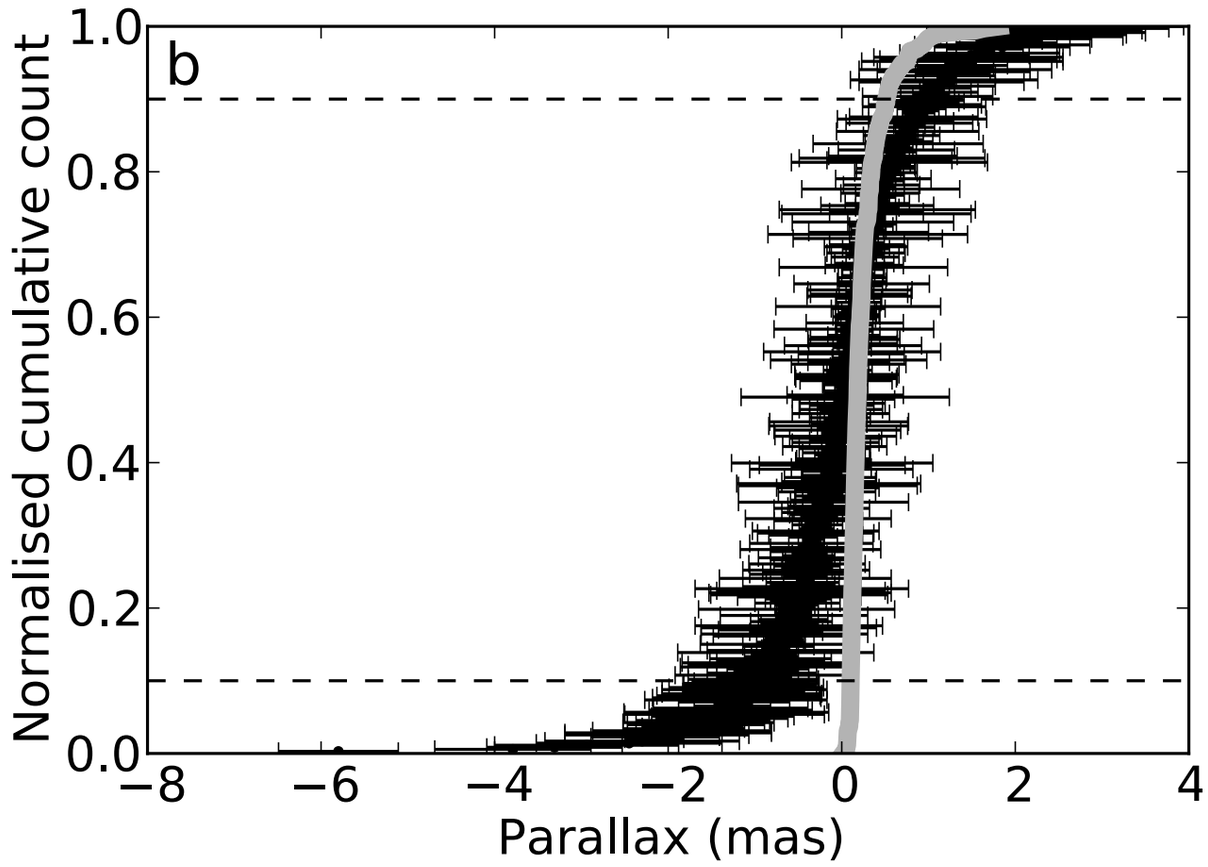
146 μas RMS

Sahlmann, Lazorenko et al., 2014, A&A in press
Lazorenko, Sahlmann et al., 2014, A&A in press

Estimating the parallax correction

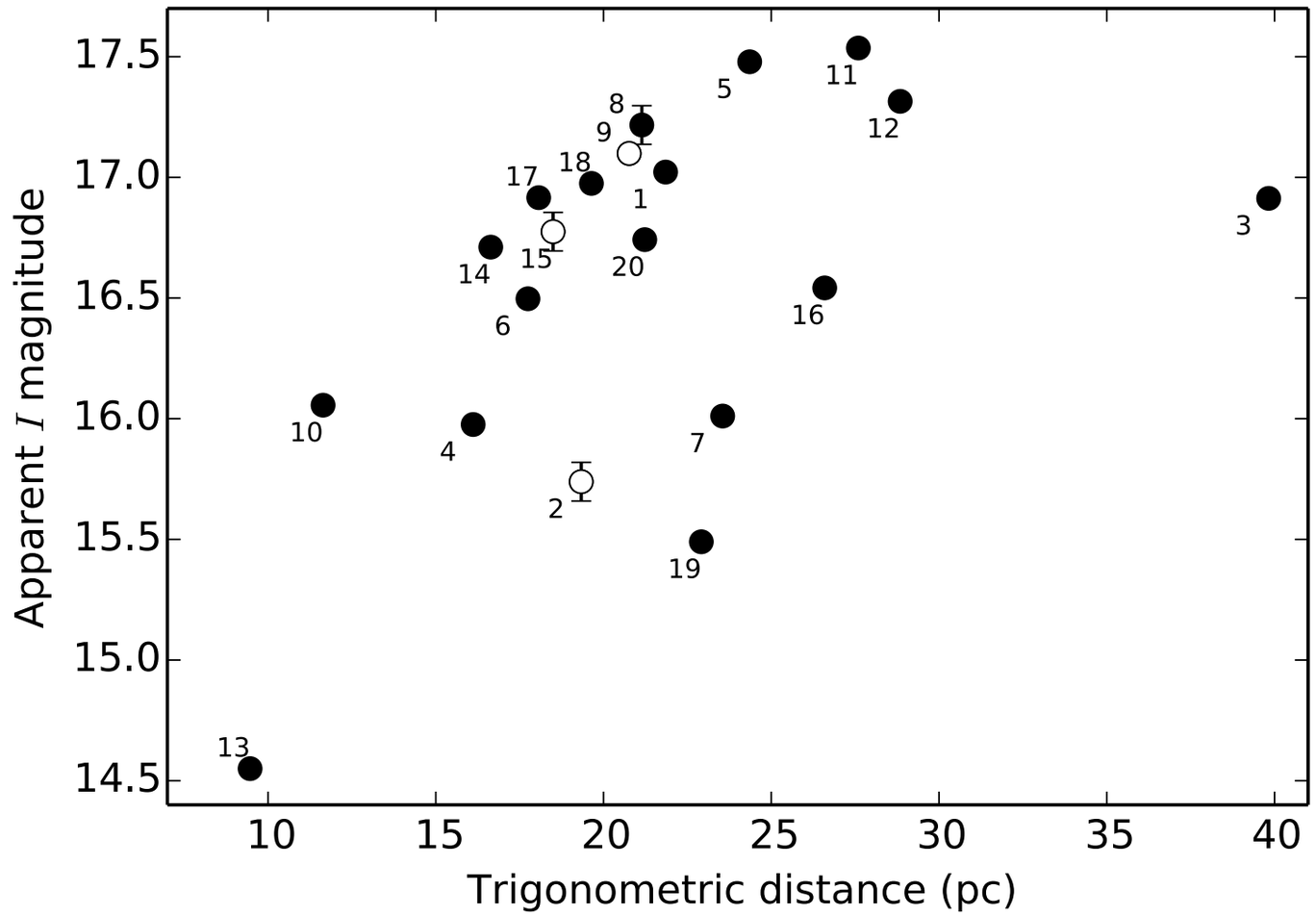
1. Absolute references (galaxies)
2. Photometric distances to ref. stars
3. Galaxy model (Besançon) - statistics





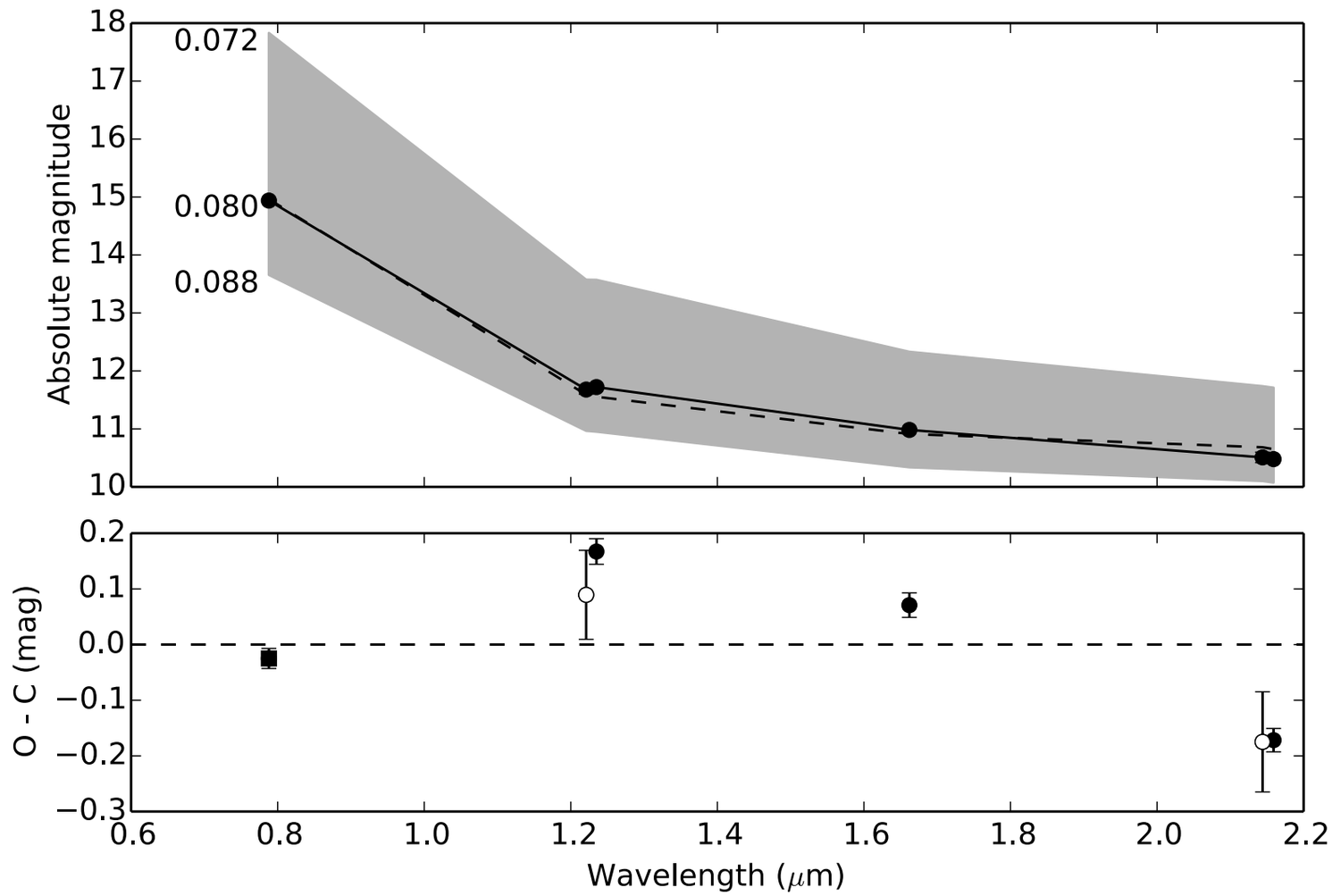
Trigonometric parallaxes of 20 M/L dwarfs at 0.1 mas

Nr	ID	$\Delta\varpi_{galax}$ (mas)	σ_{galax} (mas)	N_{stars}	ϖ_{abs} (mas)
1	DE0615−01	−0.445	0.877	194	45.700 ± 0.112
2	DE0630−18	−0.428	0.493	141	51.719 ± 0.099[a]
3	DE0644−28	−0.332	0.714	135	25.094 ± 0.094
4	DE0652−25	−0.526	0.390	106	62.023 ± 0.070
5	DE0716−06	−0.389	1.561	373	40.918 ± 0.144
6	DE0751−25	−0.327	0.429	342	56.304 ± 0.085
7	DE0805−31	−0.336	0.625	376	42.428 ± 0.083
8	DE0812−24	−0.323	0.919	364	47.282 ± 0.094
9[b]	DE0823−49	−0.062	0.643	283	48.16 ± 0.19
10	DE0828−13	−0.578	0.855	123	85.838 ± 0.148
11	DE1048−52	−0.275	0.674	565	36.212 ± 0.077
12	DE1157−48	−0.245	0.679	323	34.633 ± 0.082
13	DE1159−52	−0.332	0.495	237	105.538 ± 0.120
14	DE1253−57	−0.192	0.425	478	60.064 ± 0.054
15	DE1520−44	−0.159	0.660	414	53.995 ± 0.109
16	DE1705−54	−0.038	1.188	1184	37.549 ± 0.087
17	DE1733−16	−0.164	0.791	1530	55.272 ± 0.073
18	DE1745−16	−0.030	0.833	1511	50.871 ± 0.096
19	DE1756−45	−0.194	0.411	631	43.577 ± 0.064
20	DE1756−48	−0.057	0.560	783	47.039 ± 0.058

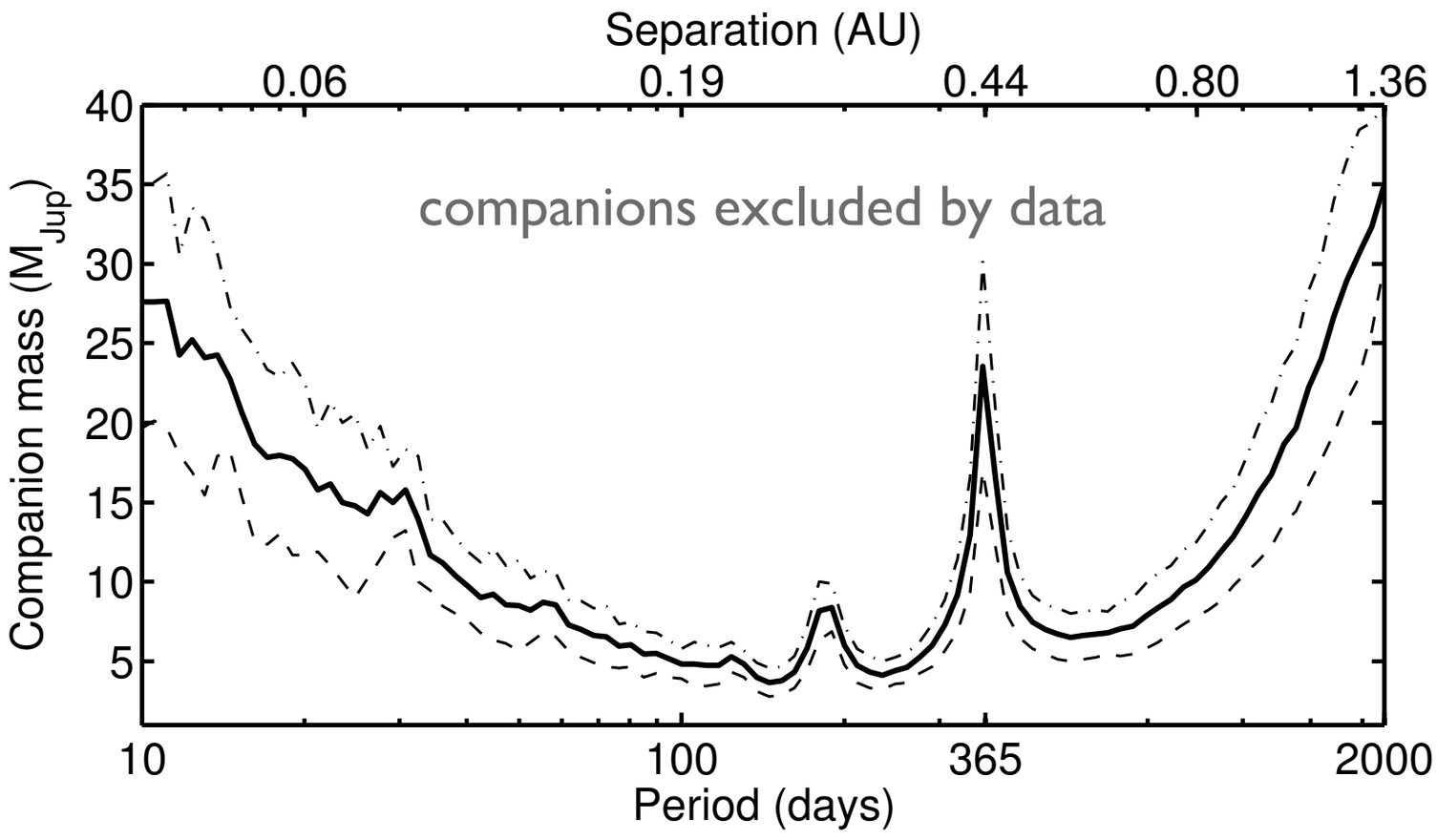


Primary mass estimation

Spectro-Photometry + distance + age estimate + BT-Settl models



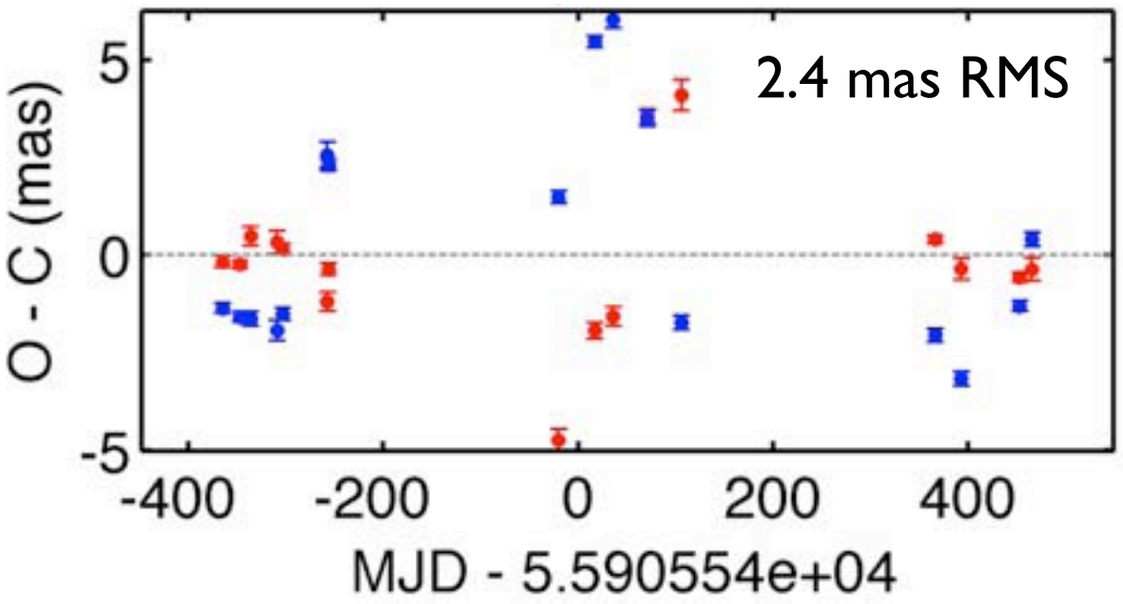
GIANT PLANETS ARE RARE AROUND ULTRACOOL DWARFS (AT ALL SEPARATIONS)

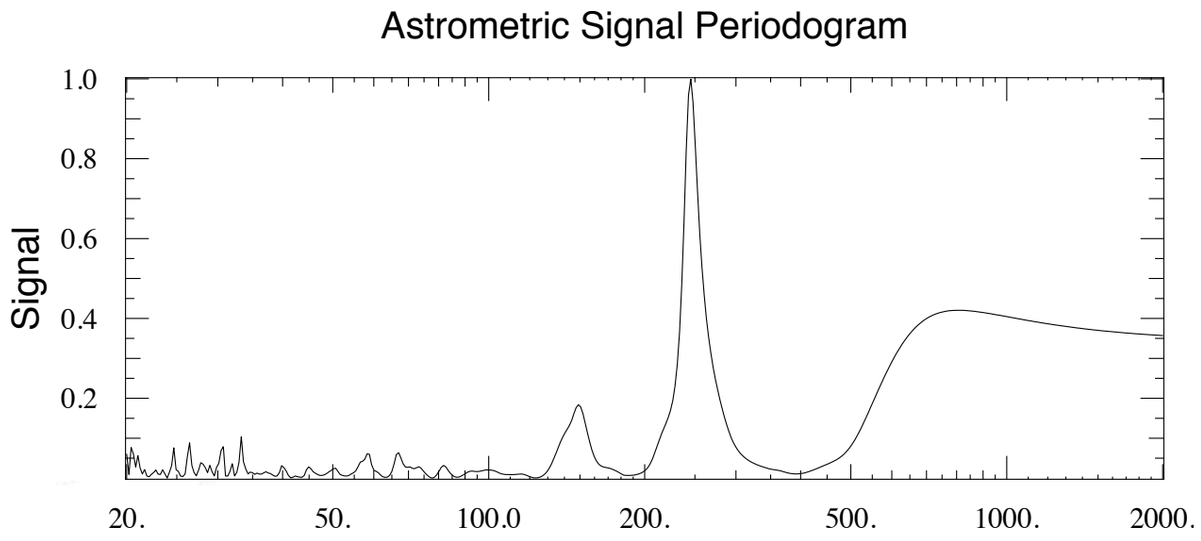


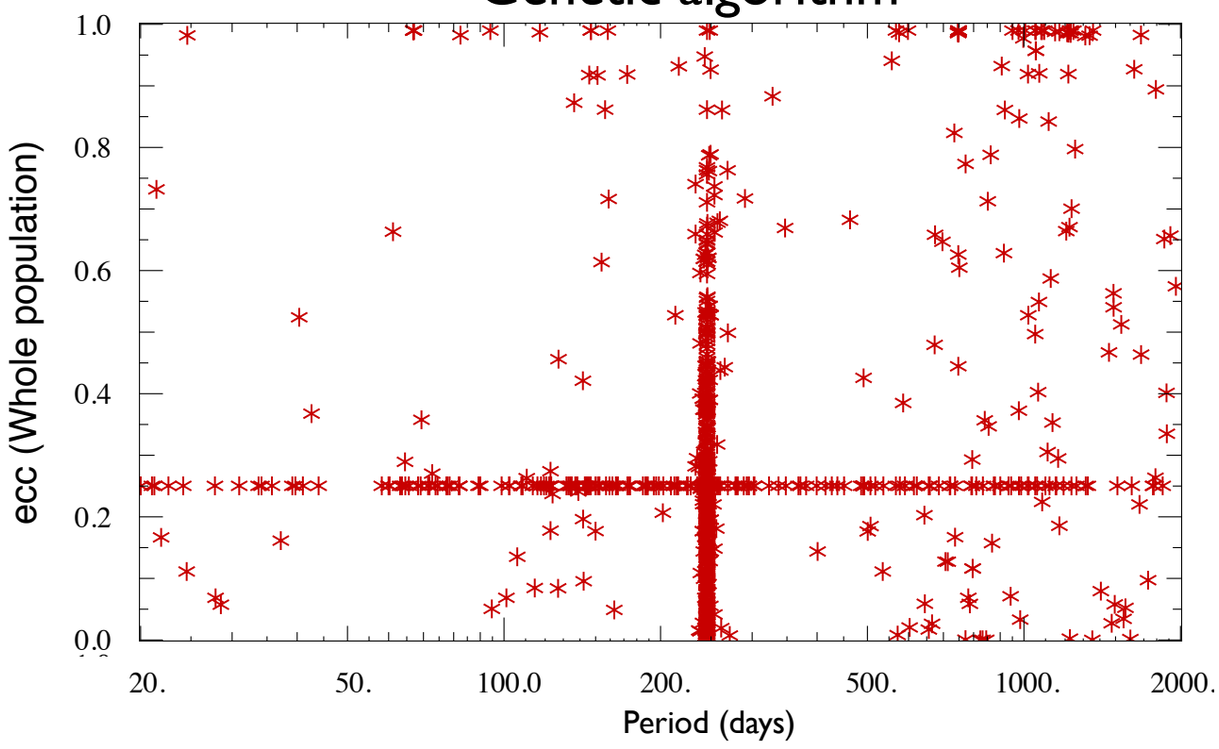
less than 9 % of M8-L2 dwarfs have a giant planet >5M_{Jup} within 0.1-0.8 AU

SEARCHING FOR PLANET SIGNATURES

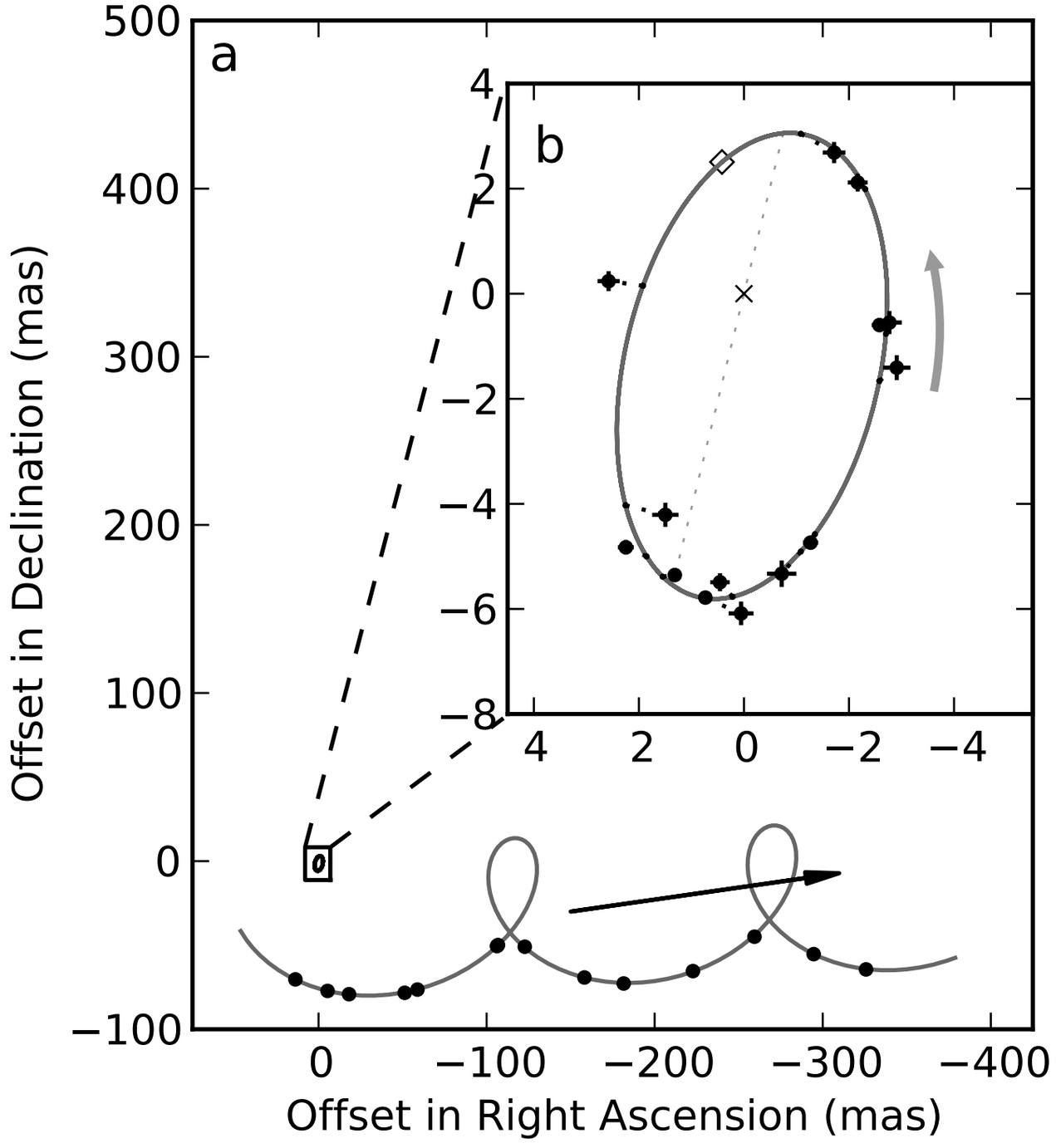
We detected some planet candidates
➔ need for more epochs and longer timespan







DETECTION OF THE ORBIT CAUSED BY A LOW-MASS COMPANION



P = 246.4 ± 1.4 days
e = 0.35 ± 0.07
a_1 = 4.61 ± 0.14 mas
Parallax = 48.16 ± 0.19 mas

M_1 = 78 ± 8 M_{Jup} (L1.5 dwarf)

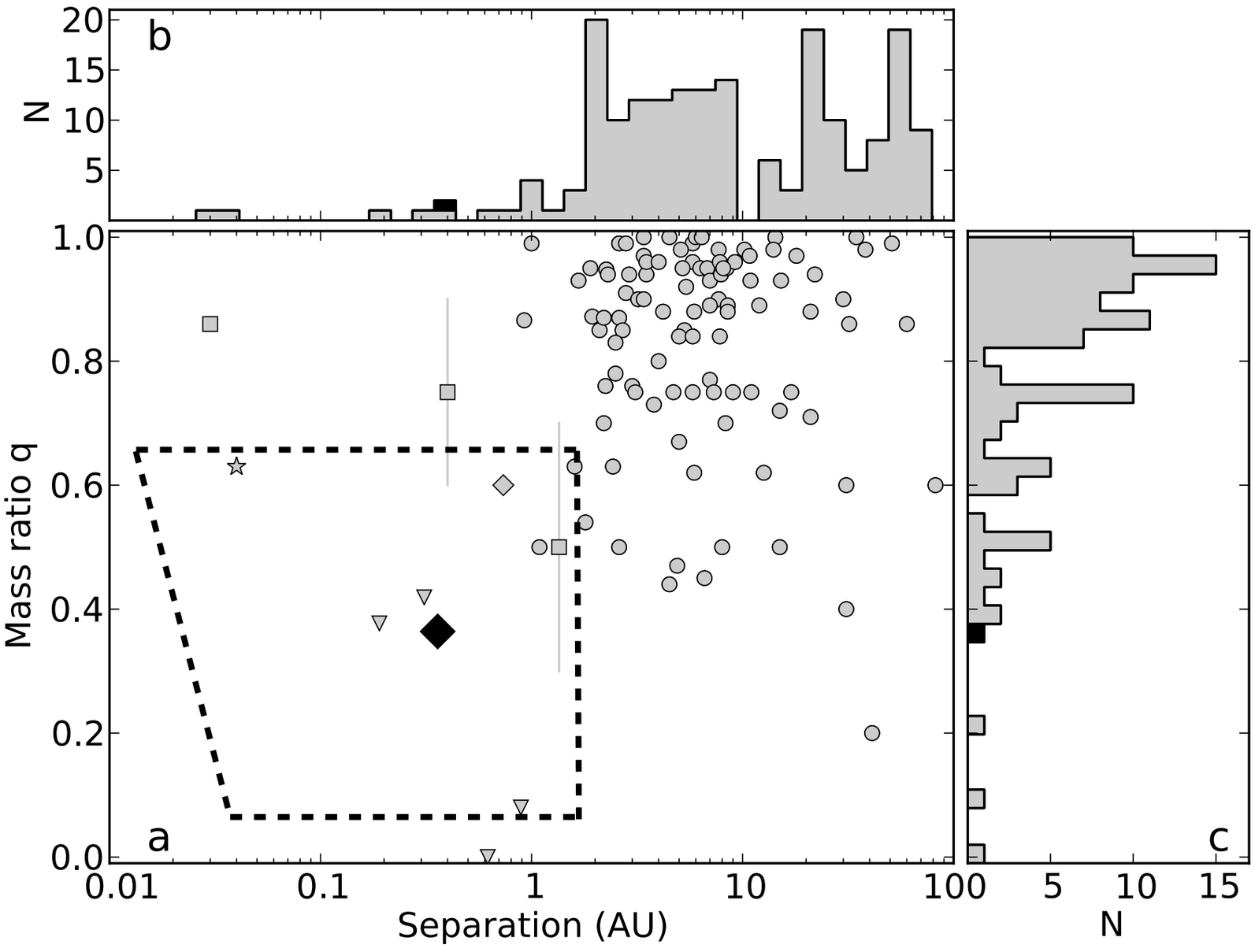
M_2 = 28.5 ± 1.9 M_{Jup}

Sahlmann et al., 2013b, A&A 556

OPENING UP A NEW DETECTION SPACE

Very low-mass binaries

(vlmbinaries.org + Dupuy compilation + literature)



Precision astrometry of VLM binaries:

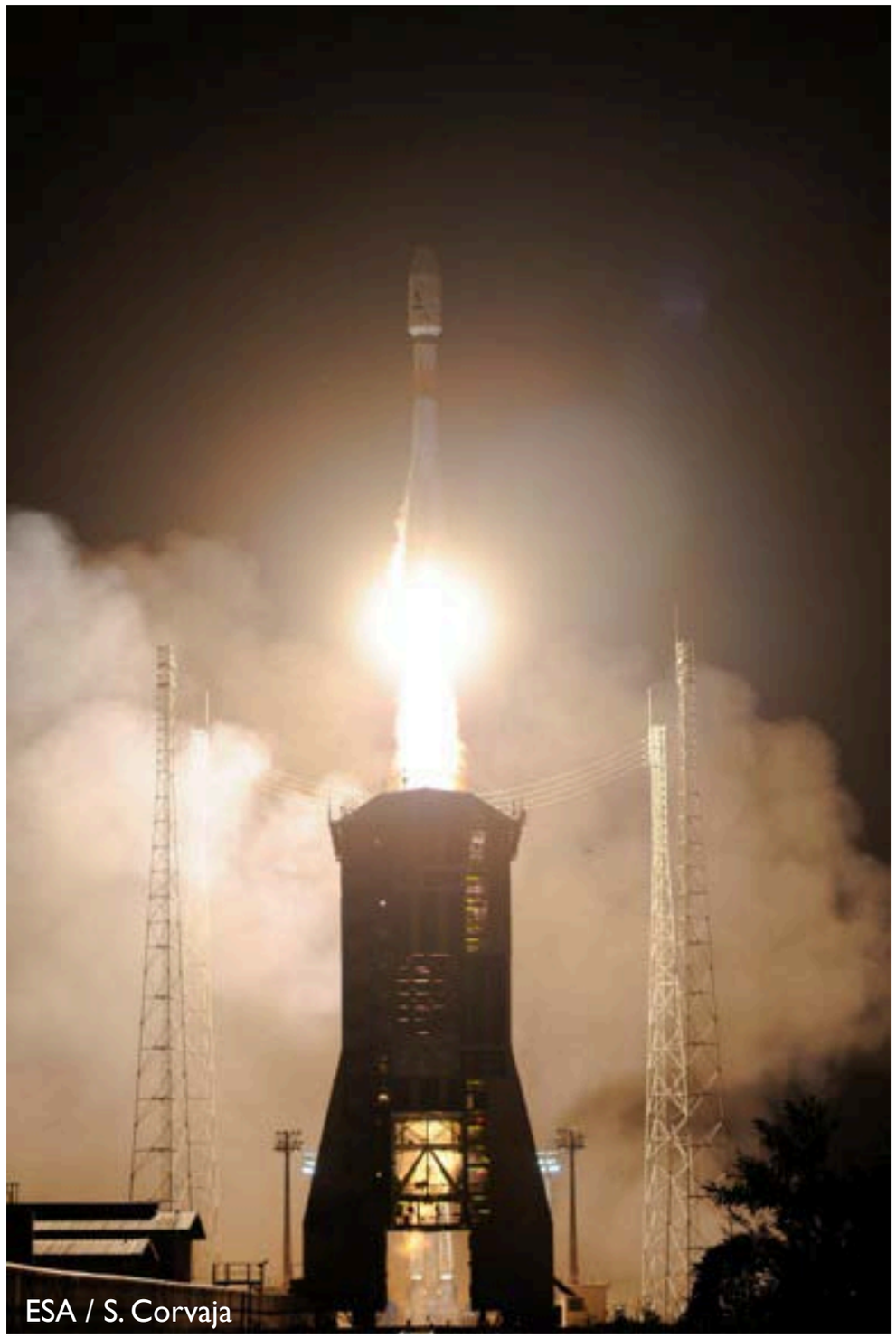
1. A new window to small mass-ratio systems.

2. Companion mass function down to planetary masses

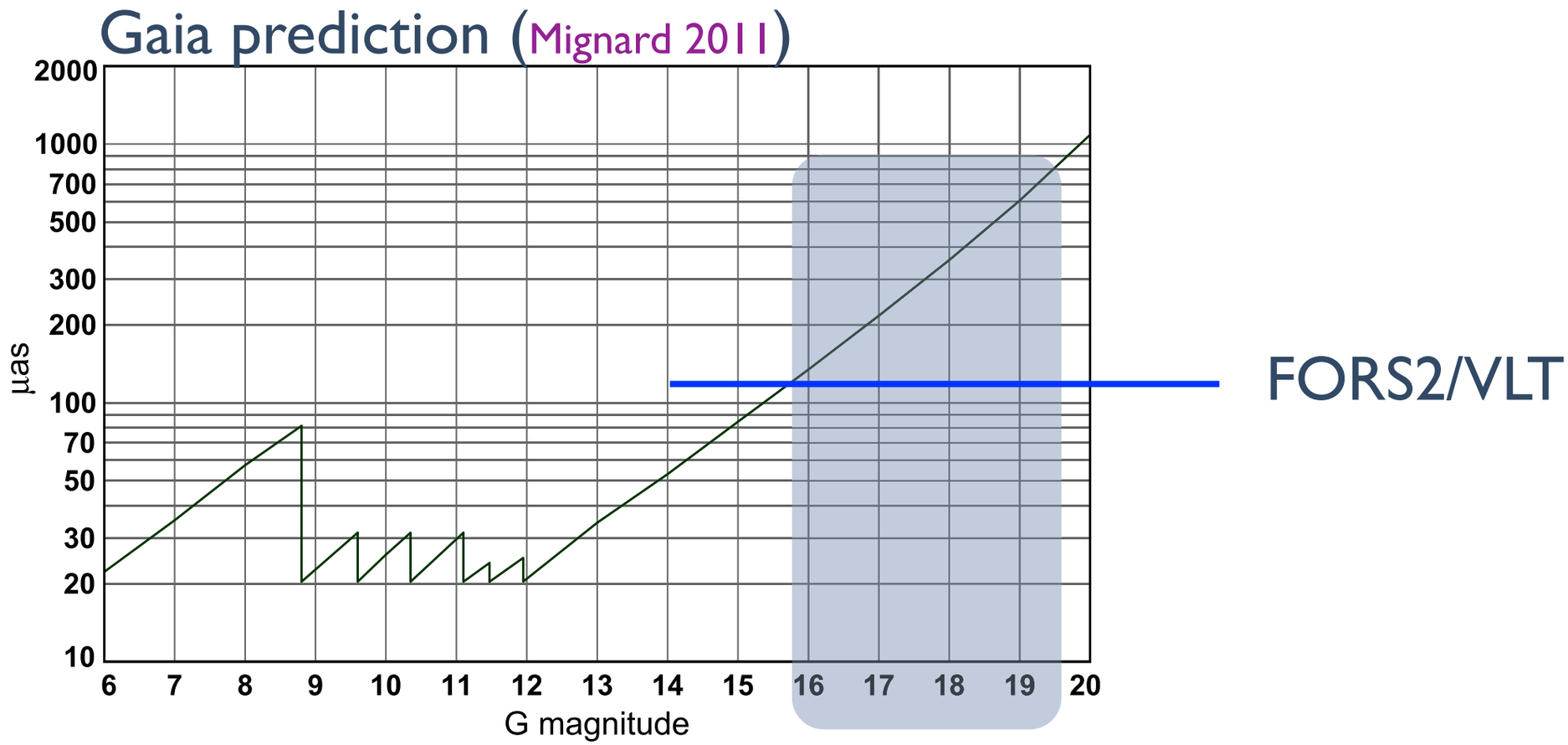
3. Complete orbit characterisation + high-precision parallax

4. Multiplicity: 10^{+11}_{-3} % of M8-L2 dwarfs are tight binaries

THE GAIA CONTEXT

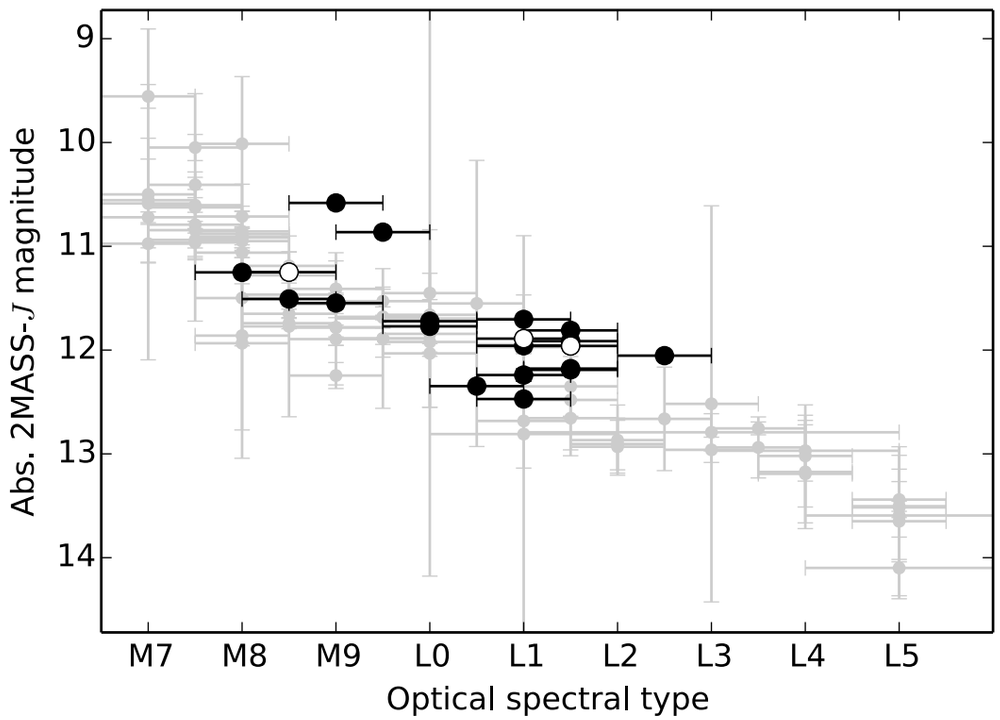


FAINT STAR PRECISION WITH FORS2 AND GAIA



FORS2/VLT and Gaia reach comparable precisions on faint single objects located in dense fields (factor of ~65 in light-collecting area)

ULTRACOOL DWARF SCIENCE WITH GAIA

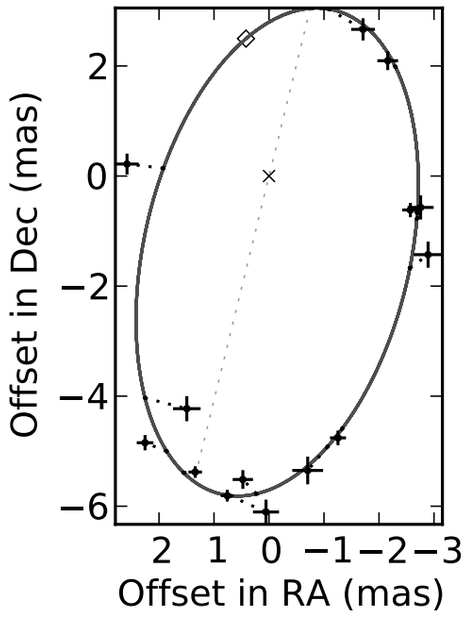


Accurate distances for ~1000 very-low mass stars and brown dwarfs
➔ colour magnitude diagrams
➔ better understanding of physics at the stellar/ substellar boundary

(Smart et al., 2008, IAUS 248; Sarro et al., 2013, A&A, 550)

Statistics of very low-mass binaries: insights into the question whether they form like stellar binaries

Planets around ultracool dwarfs: identify candidates for ground-based follow-up



CONCLUSIONS

Ground-based astrometry can deliver long-term accuracies at 100 micro-arcsec level over several years.

Super-Jupiters are rare around M/L-transition dwarfs at all separations.

We discovered 2 new tight UCD binaries and several planet candidates.

ESA's Gaia mission will deliver high-precision astrometry for hundreds of UCD, yielding accurate distances, astrometric binary orbits, and UCD planet candidates.

arXiv:1403.1275

Astrometric planet search around southern ultracool dwarfs

I. First results, including parallaxes of 20 M8–L2 dwarfs⋆

J. Sahlmann[1,2], P. F. Lazorenko[3], D. Ségransan[2], E. L. Martín[4], M. Mayor[2], D. Queloz[2,5], and S. Udry[2]

[1] European Space Agency, European Space Astronomy Centre, P.O. Box 78, Villanueva de la Cañada, 28691 Madrid, Spain
e-mail: johannes.sahlmann@sciops.esa.int
[2] Observatoire de Genève, Université de Genève, 51 Chemin Des Maillettes, 1290 Versoix, Switzerland
[3] Main Astronomical Observatory, National Academy of Sciences of the Ukraine, Zabolotnogo 27, 03680 Kyiv, Ukraine
[4] INTA-CSIC Centro de Astrobiología, 28850 Torrejón de Ardoz, Madrid, Spain
[5] University of Cambridge, Cavendish Laboratory, J J Thomson Avenue, Cambridge, CB3 0HE, UK

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Astrometric planet search around southern ultracool dwarfs

II. Astrometric reduction methods and a deep astrometric catalogue⋆

P. F. Lazorenko[1], J. Sahlmann[2,3], D. Ségransan[3], E. L. Martín[4], M. Mayor[3], D. Queloz[3,5], and S. Udry[3]

[1] Main Astronomical Observatory, National Academy of Sciences of the Ukraine, Zabolotnogo 27, 03680 Kyiv, Ukraine
e-mail: laz@mao.kiev.ua
[2] European Space Agency, European Space Astronomy Centre, P.O. Box 78, Villanueva de la Cañada, 28691 Madrid, Spain
[3] Observatoire de Genève, Université de Genève, 51 Chemin Des Maillettes, 1290 Versoix, Switzerland
[4] INTA-CSIC Centro de Astrobiología, 28850 Torrejón de Ardoz, Madrid, Spain
[5] University of Cambridge, Cavendish Laboratory, J J Thomson Avenue, Cambridge, CB3 0HE, UK

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