Long-term astrometric monitoring and orbit constraint of sub-stellar companions

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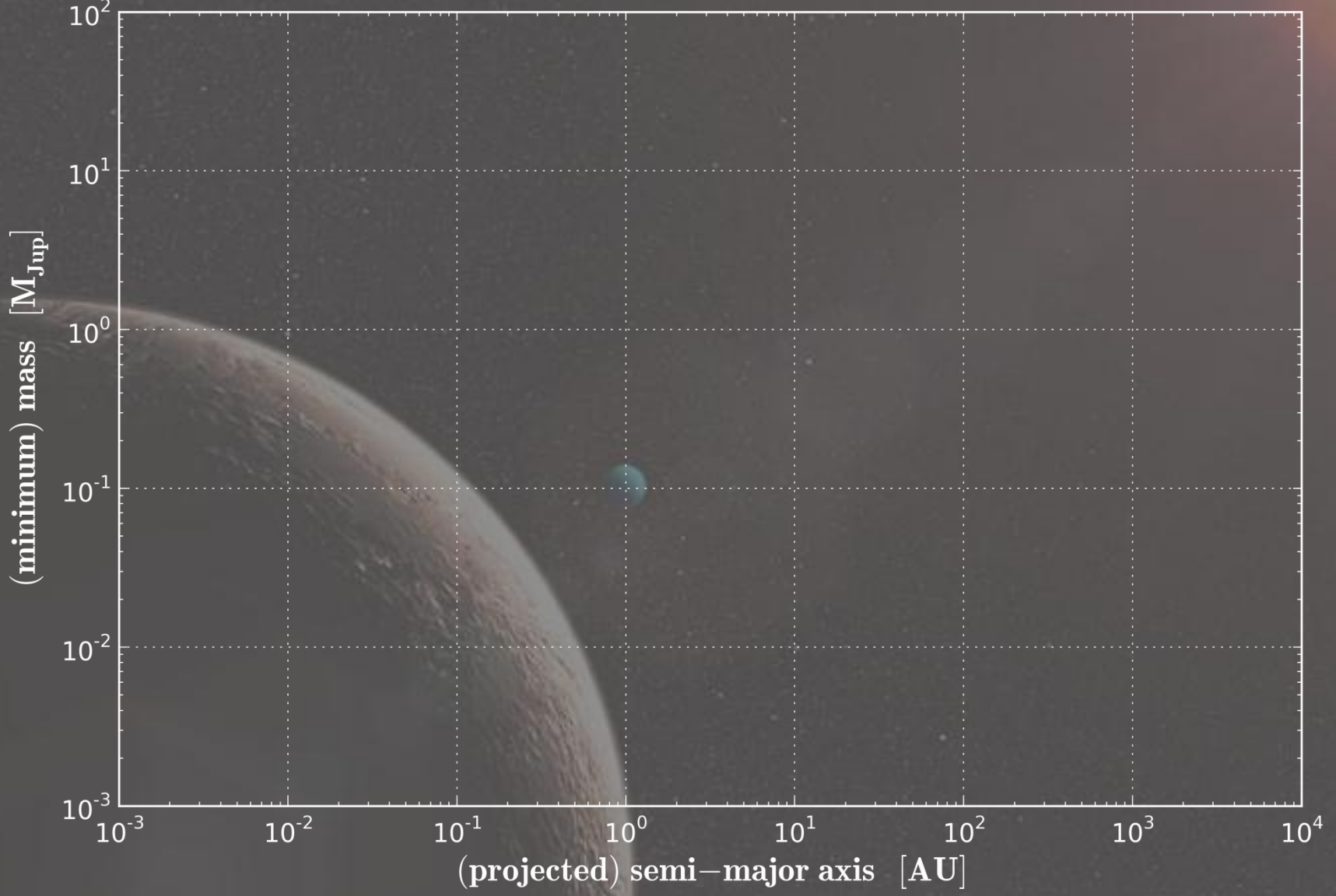
AIU Jena

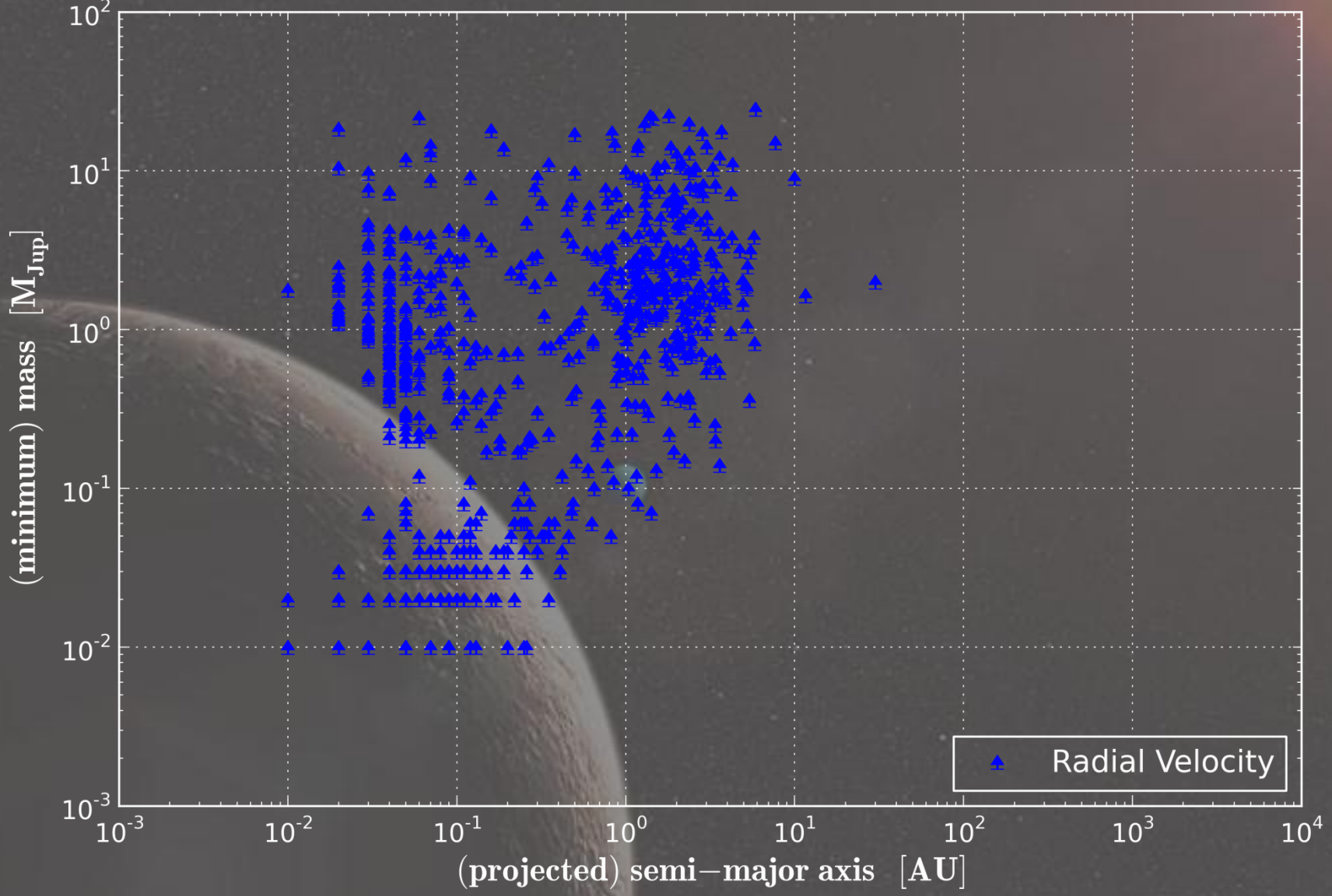
„**Exoplanet Observations with the E-ELT** “
5th February 2014


Motivation

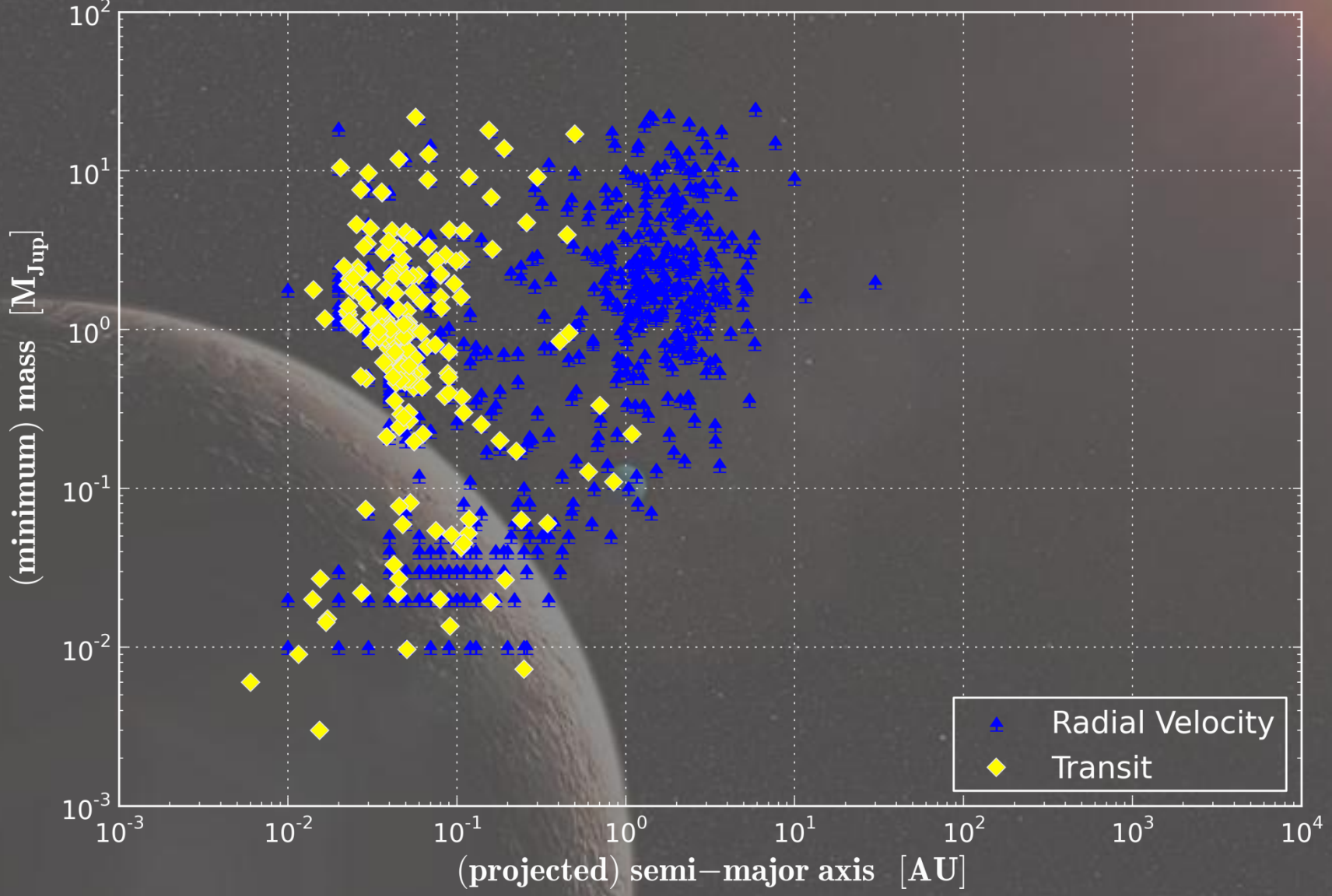
Detection Methods



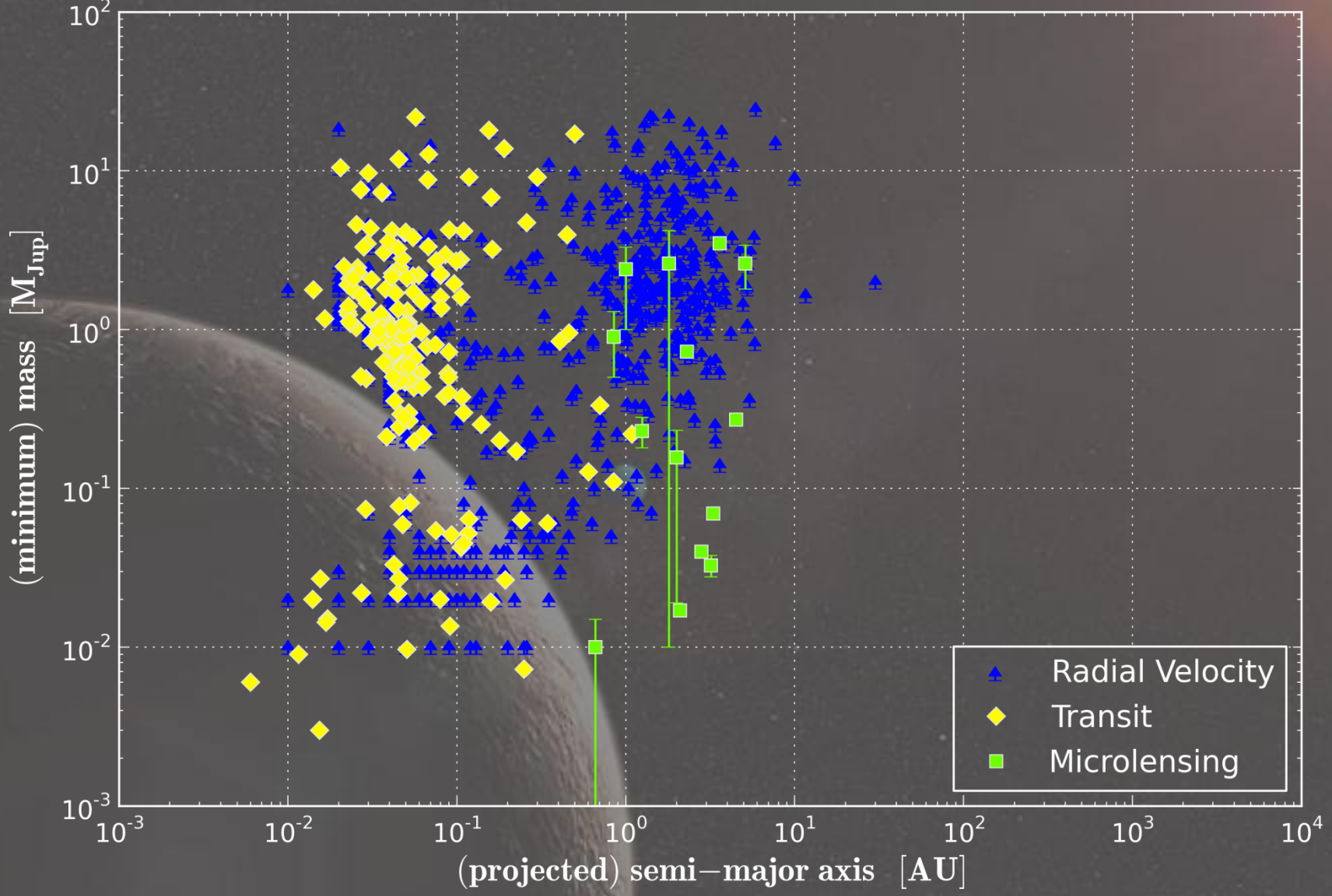
Detection Methods



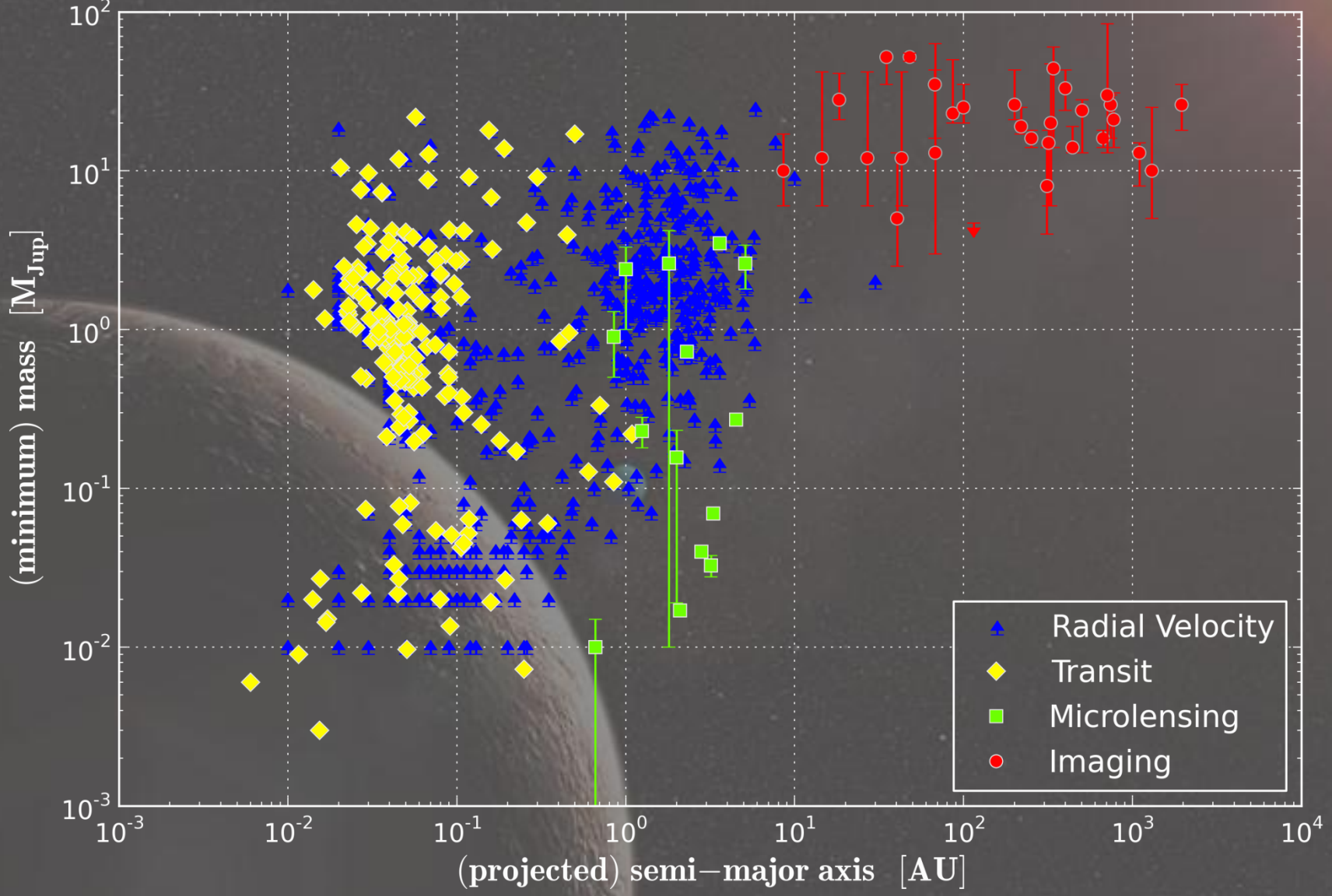
Detection Methods



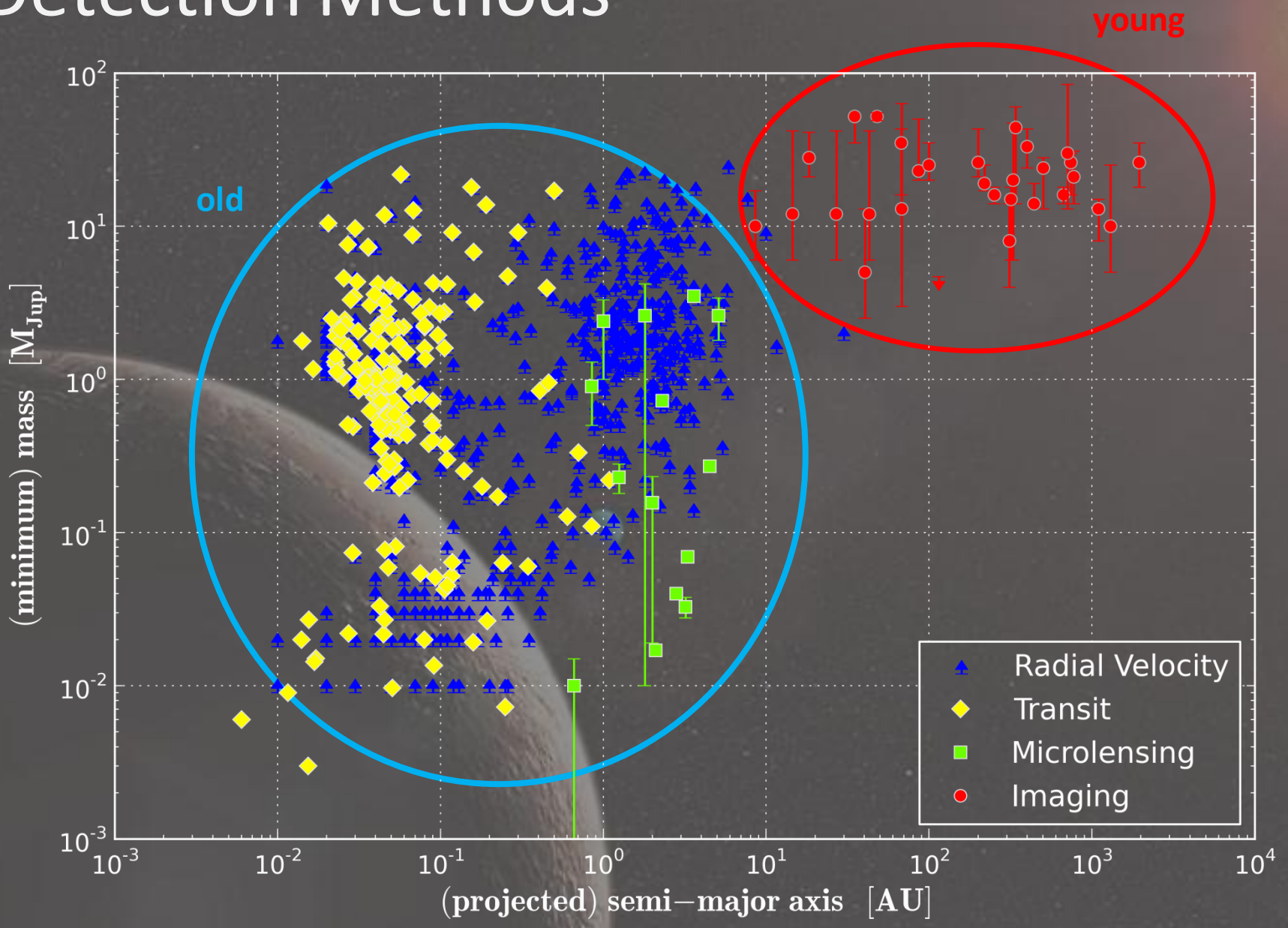
Detection Methods



Detection Methods



Detection Methods




What can astrometric monitoring tell us?

Astrometric monitoring

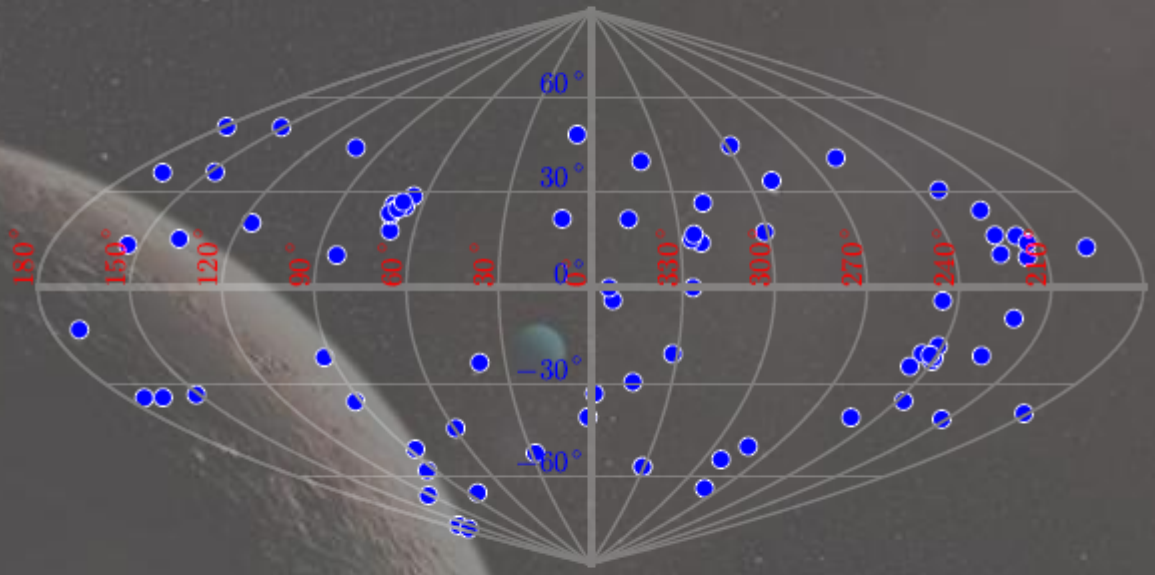
- Orbit eccentricities are indicators for formation history
- Eccentricity and inclination tell us where to look for further-in planets
- We confirm that systems are gravitationaly bound
- Dynamical mass determination will be possible eventually

Observations

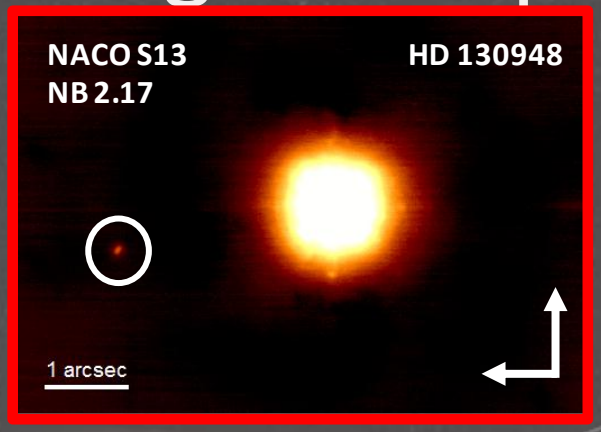
and

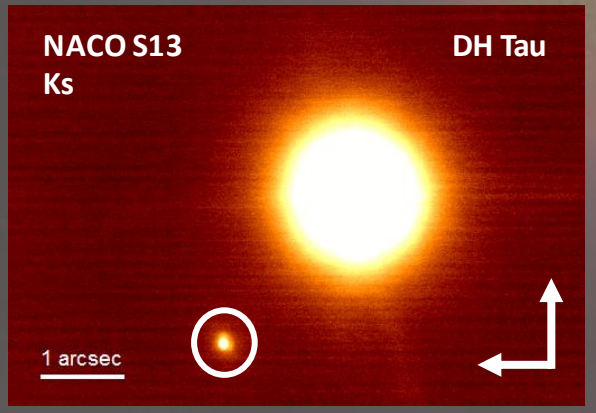
Astrometric Measurements

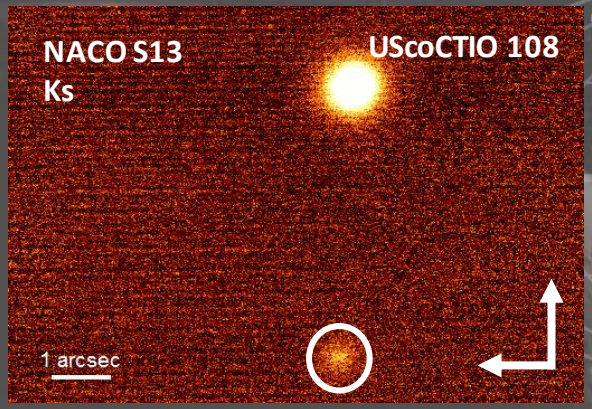
Known Directly Imaged Sub-stellar Companions

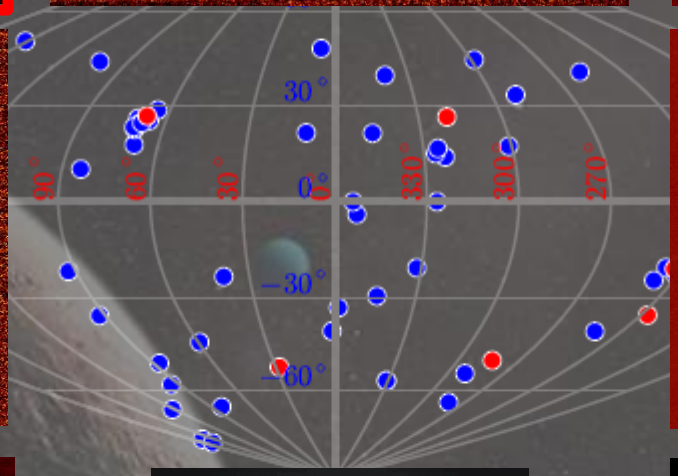


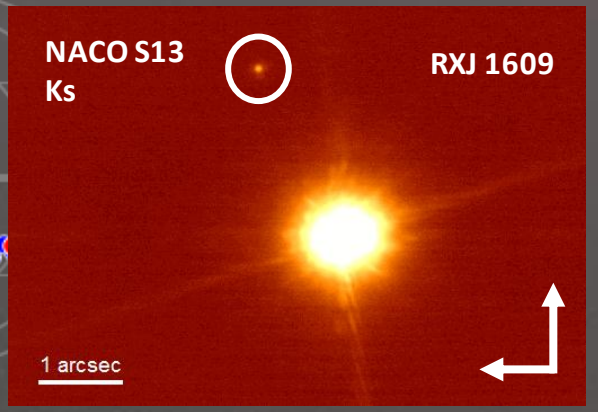
Target Sample

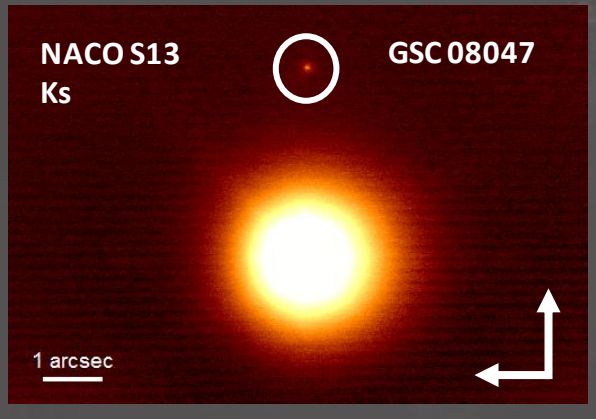


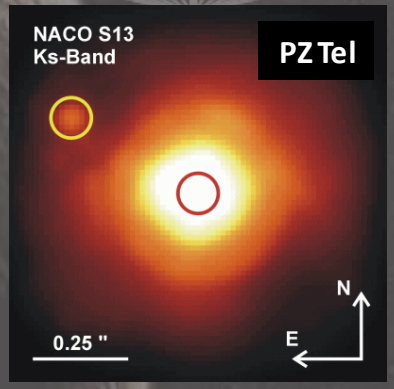


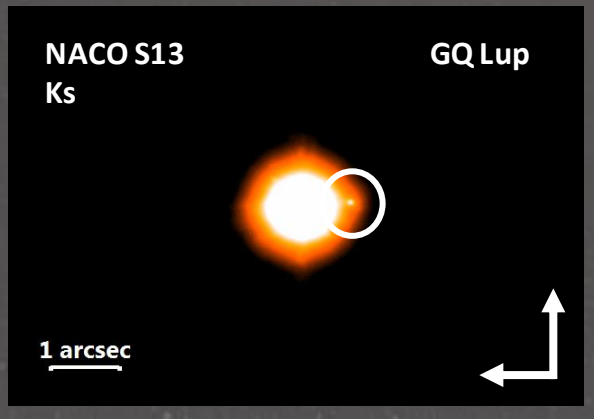




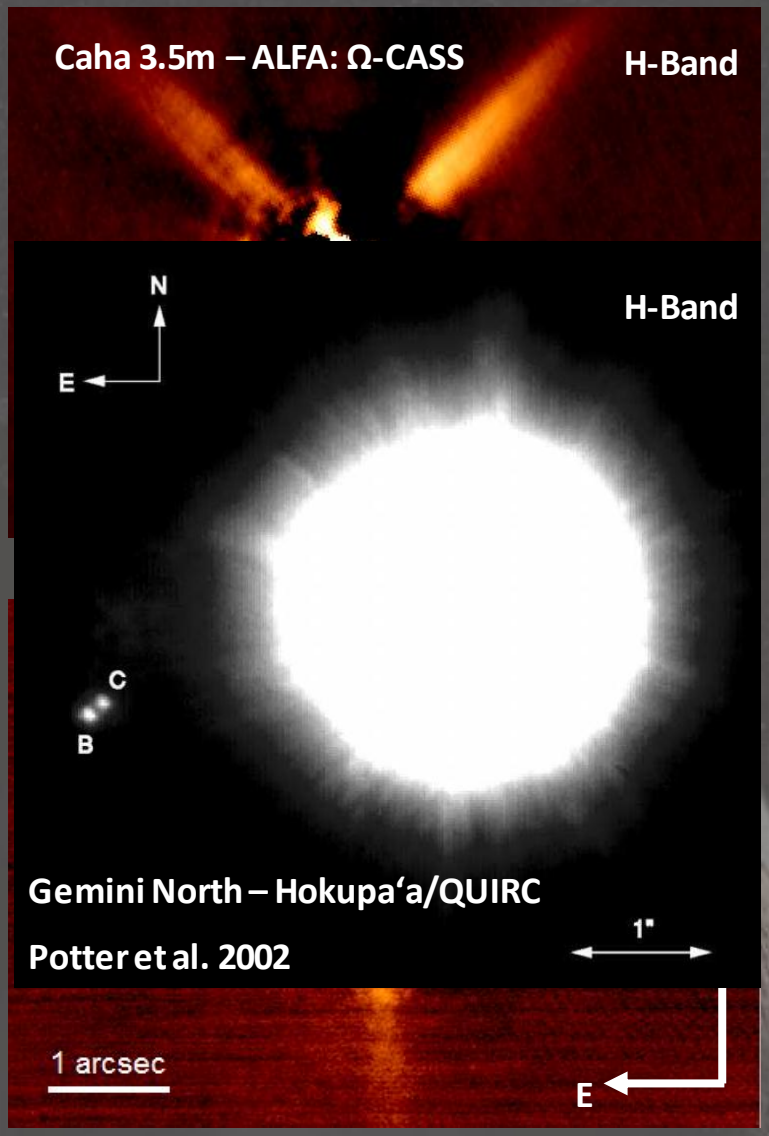








Observations – HD130948



The Primary

R.A.	$14^h\,50^m\,15^s.81$
Dec	$23°\,54'\,42''.6$
Spectral Type	G 1 V
Mass [$M_\odot$]	1
Age [Myr]	790^{+220}_{-150}
Distance [pc]	18.17 ± 0.11

The Companion

Discovery Year	2001
Separation [arcsec]	2.64 ± 0.01
Proj. Separation [AU]	48 ± 2
Position Angle [°]	104.5 ± 0.5
Spectral Type	$dL2 \pm 2$ / $dL2 \pm 2$
Mass Estimate [$M_\odot$]	<0.075 / <0.065

Dupuy & Liu 2011: $0.1095 \pm 0.0022\ M_\odot$

Observations – HD130948

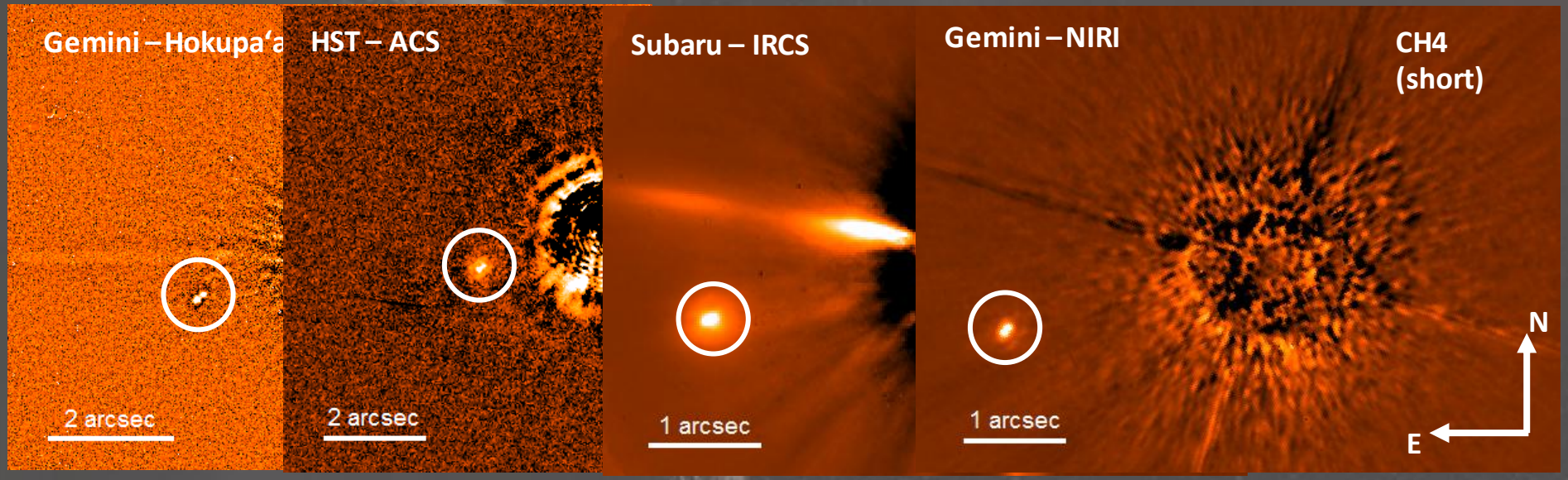
Date	Instrument	Filter	DIT [s]	NDIT	NExp
2002-04-26	Caha 3.5 m/Ω-Cass	H	0.842	49	24
2006-04-15	Caha 3.5 m/Ω-Cass	H	0.842	49	28
2009-07-03	VLT/NACO	NB 2.17	0.4	149	21


Very Large Telescope, Chile


Calar Alto Observatory, Spain

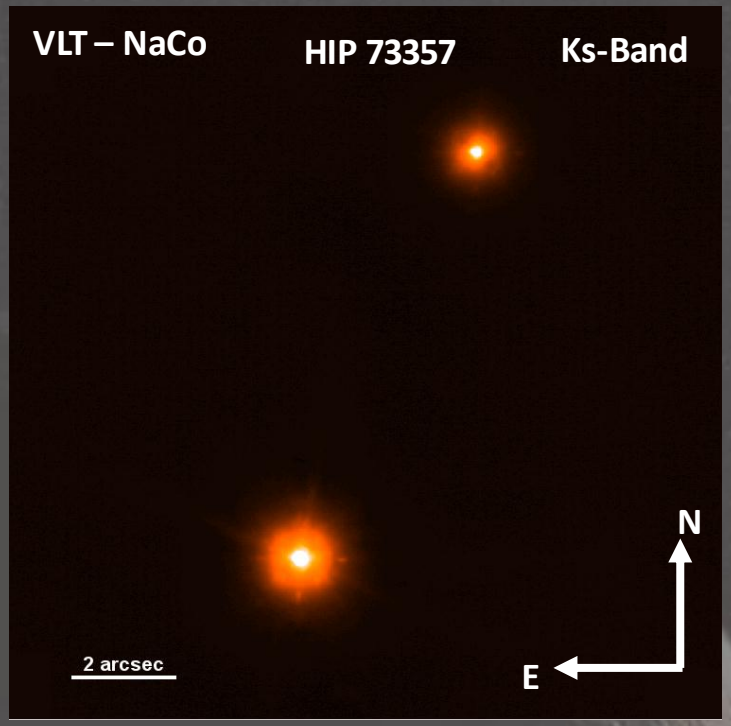
Archive Data – HD130948

Date	Telescope	Instrument	Filter	exposure time [s]
2001-06-28	Gemini-North	Hokupaa+QuIRC	H	6×0.5
2002-04-23	Gemini-North	Hokupaa+QuIRC	H	16×5
2002-09-06	HST	ACS	F850LP	200
2003-05-21	Subaru	IRCS	H	$19 \times 4 \times 5$
2005-02-23	HST	ACS	F850LP	300
2005-04-17	Gemini-North	NIRI	CH4(short)	$90 \times 1 \times 30$

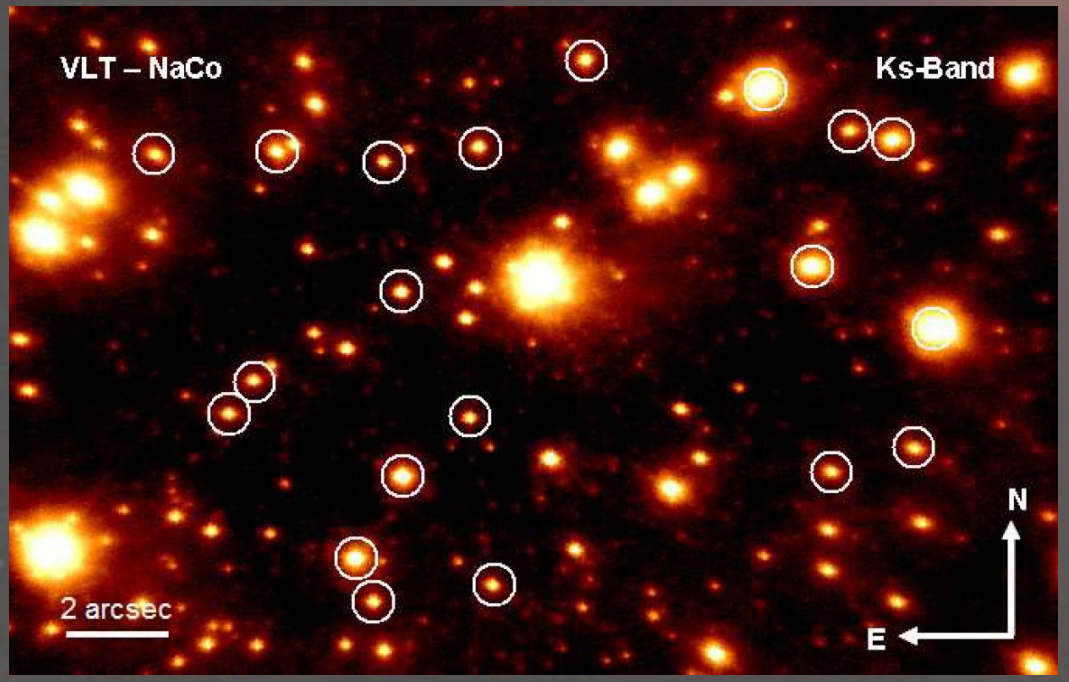


Astrometric Calibration

Binaries



Cluster 47 Tuc



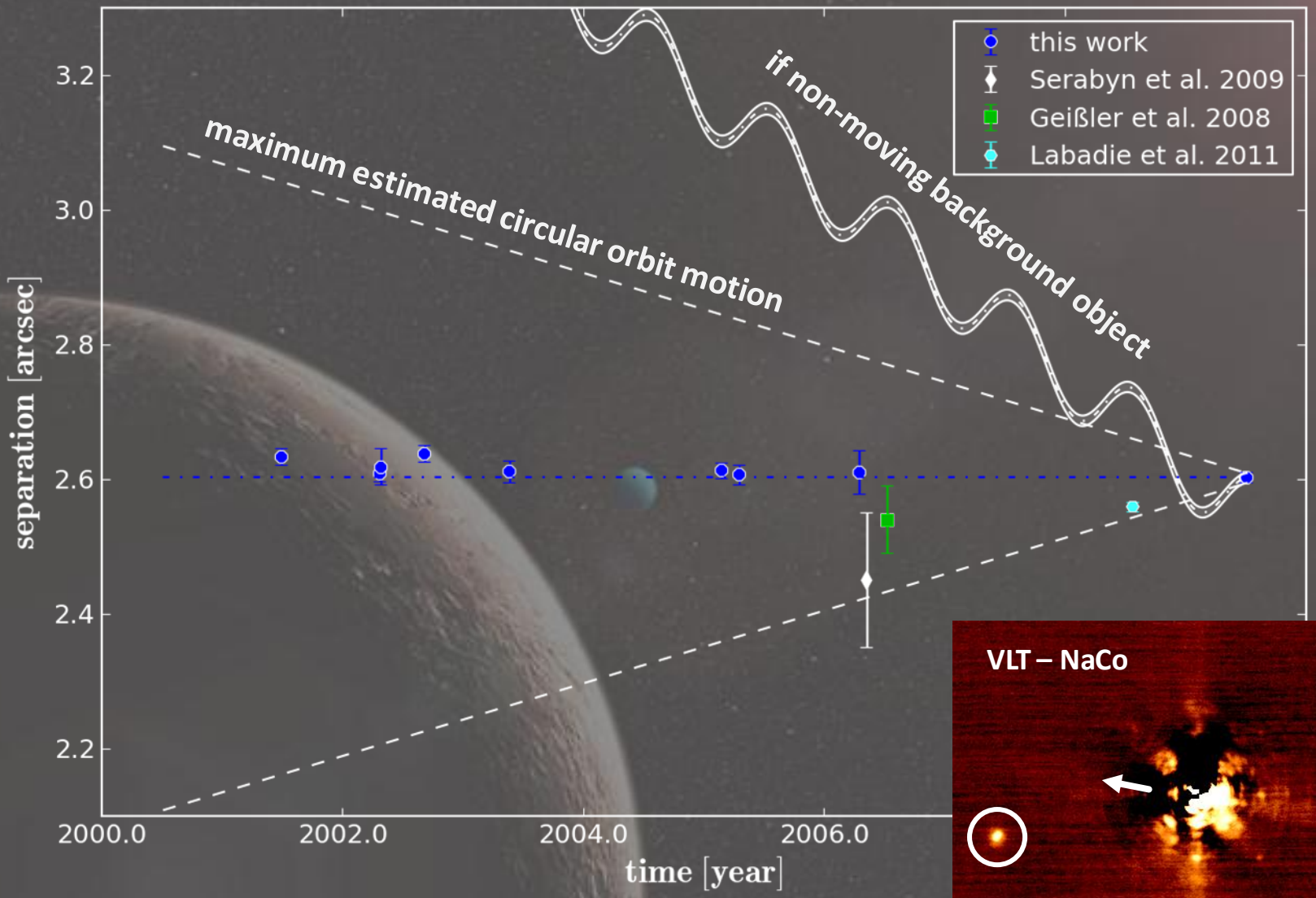
Measurement of relative positions of cluster members or binary

Comparison with absolute reference frame (HST, Hip…)

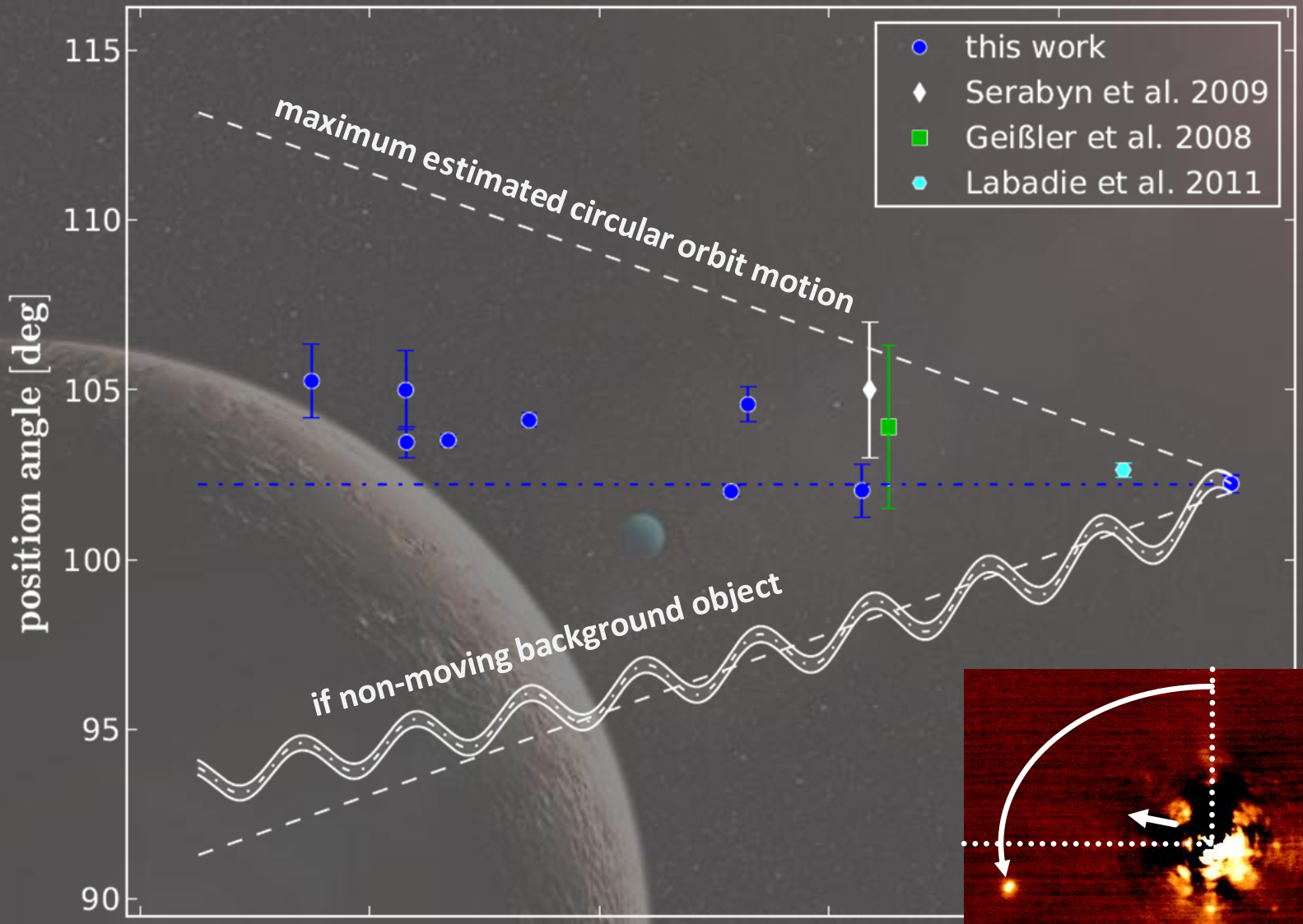
Proper motion correction

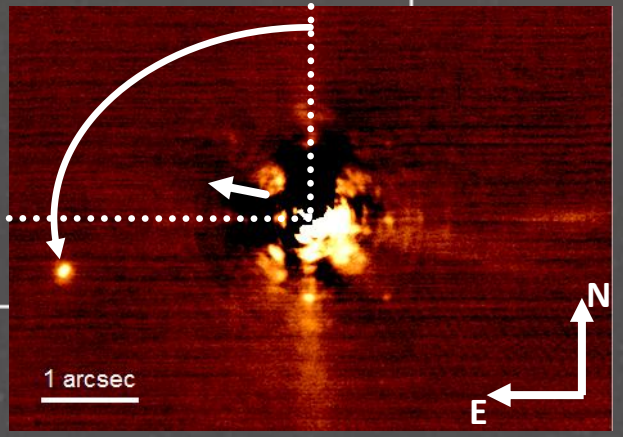
Computation of detector pixel scale and orientation

Astrometric Results – HD130948

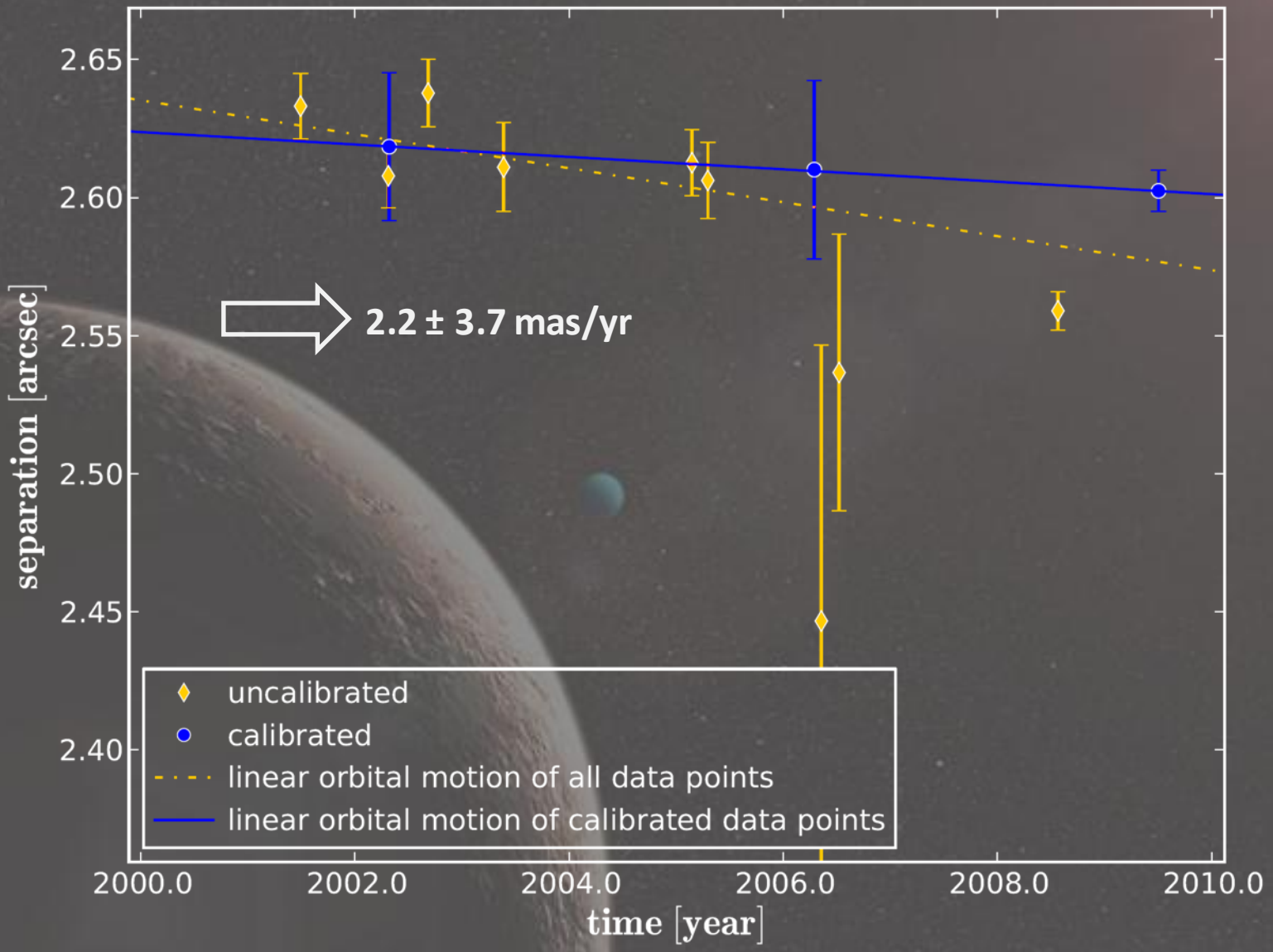


Astrometric Results – HD130948

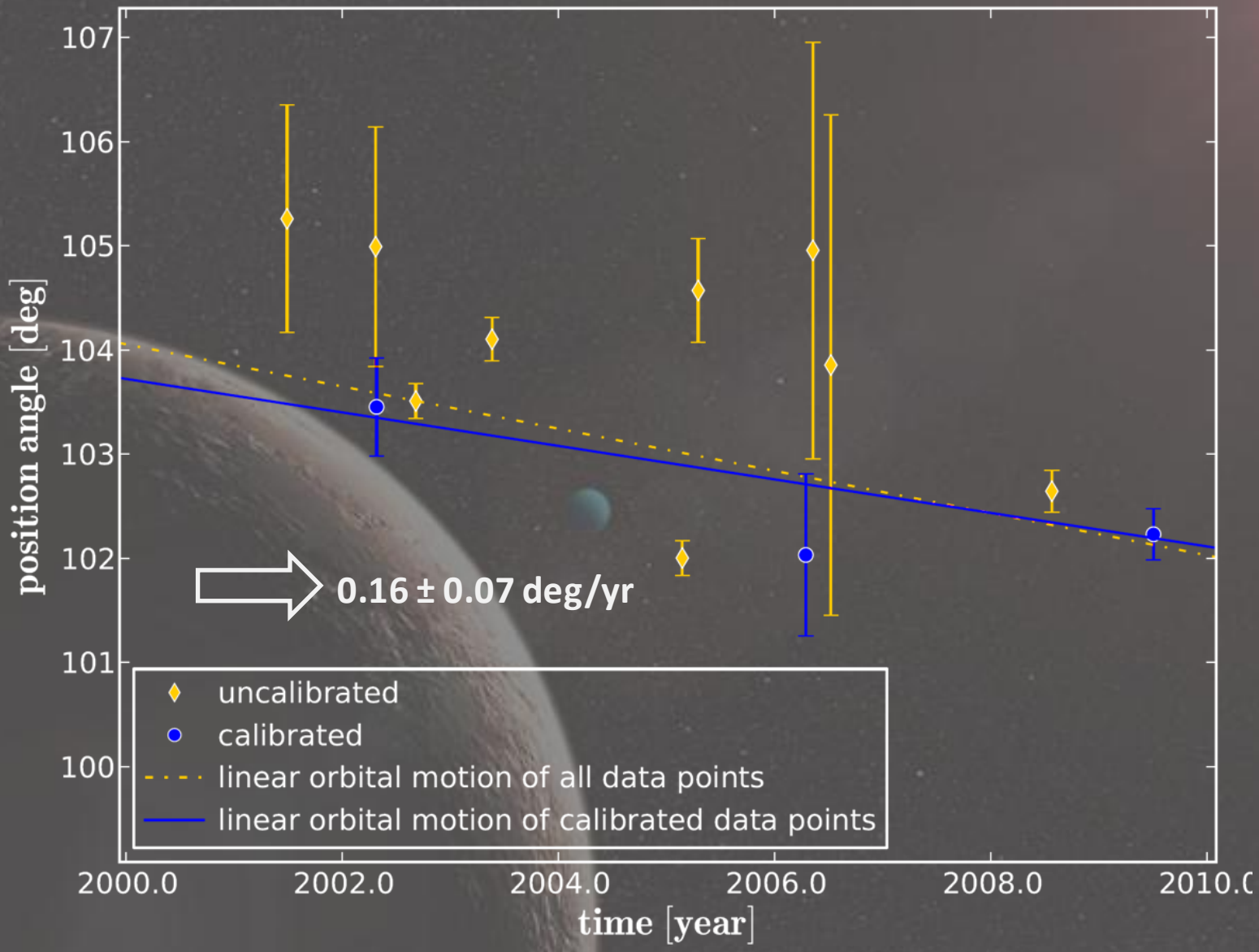




Astrometric Results – HD130948



Astrometric Results – HD130948

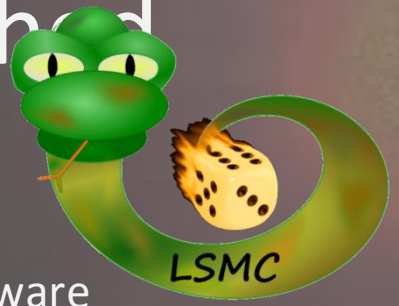


Orbit Fitting

C. Ginski

2014 February 6th

Least-Squares Monte-Carlo Method



Implemented in **Python**

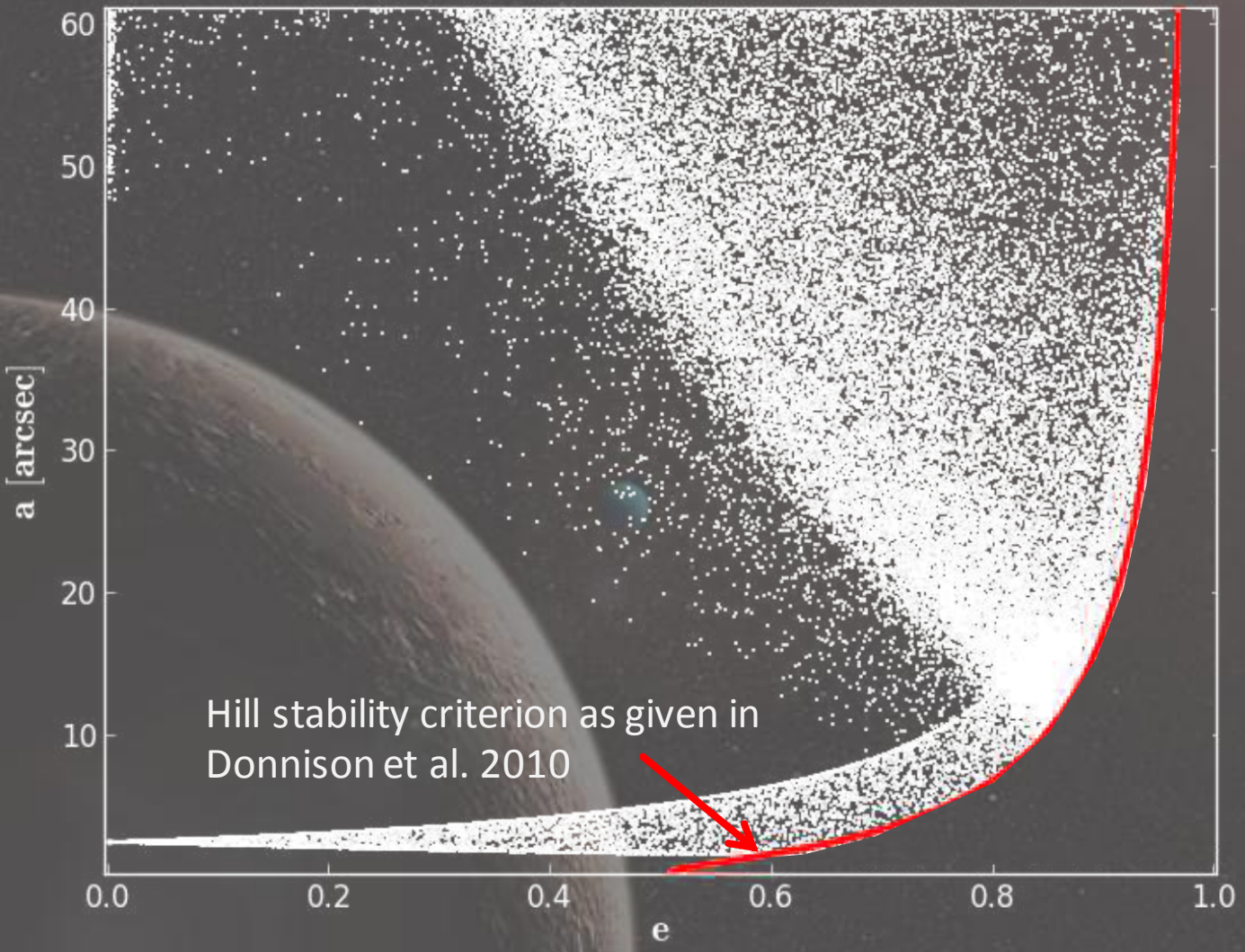
SciPy (E. Jones, T. Oliphant , P. Peterson et al. 2001) - open-source software for mathematics, science, and engineering

NumPy (D. Ascher et al. 1999) - fundamental package for scientific computing with Python

Matplotlib (J. Hunter et al. 2007) - python 2D plotting library which produces publication quality figures

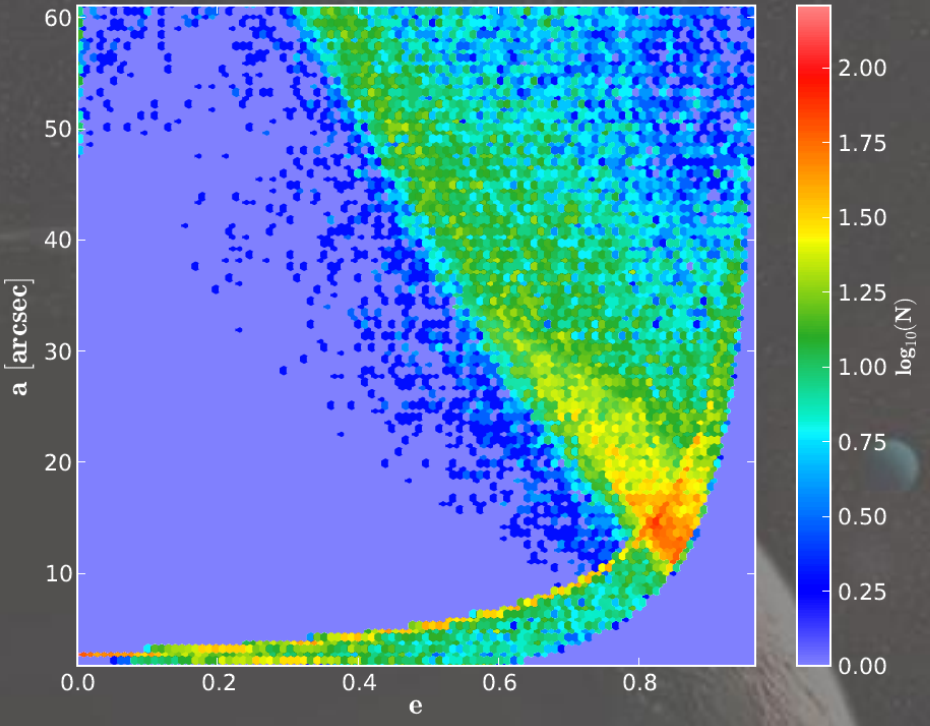
Input measurements and constraints for orbital elements → First guess from uniform distribution → Levenberg-Marquardt optimization → Repeat x 1,000,000

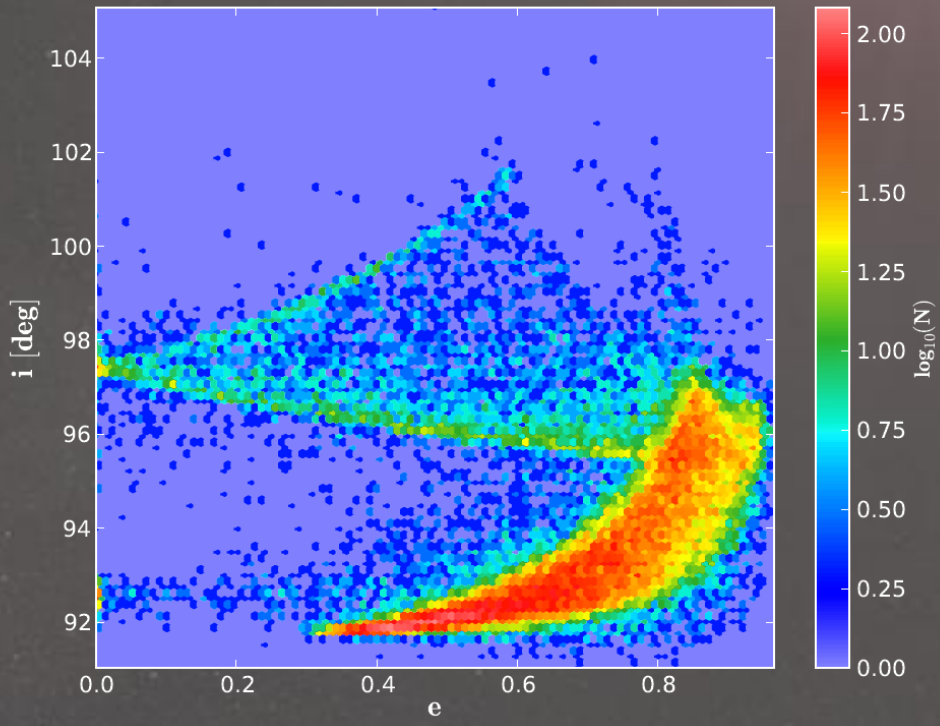
Results - HD130948



Ginski et al. 2013, MNRAS, 434, 671

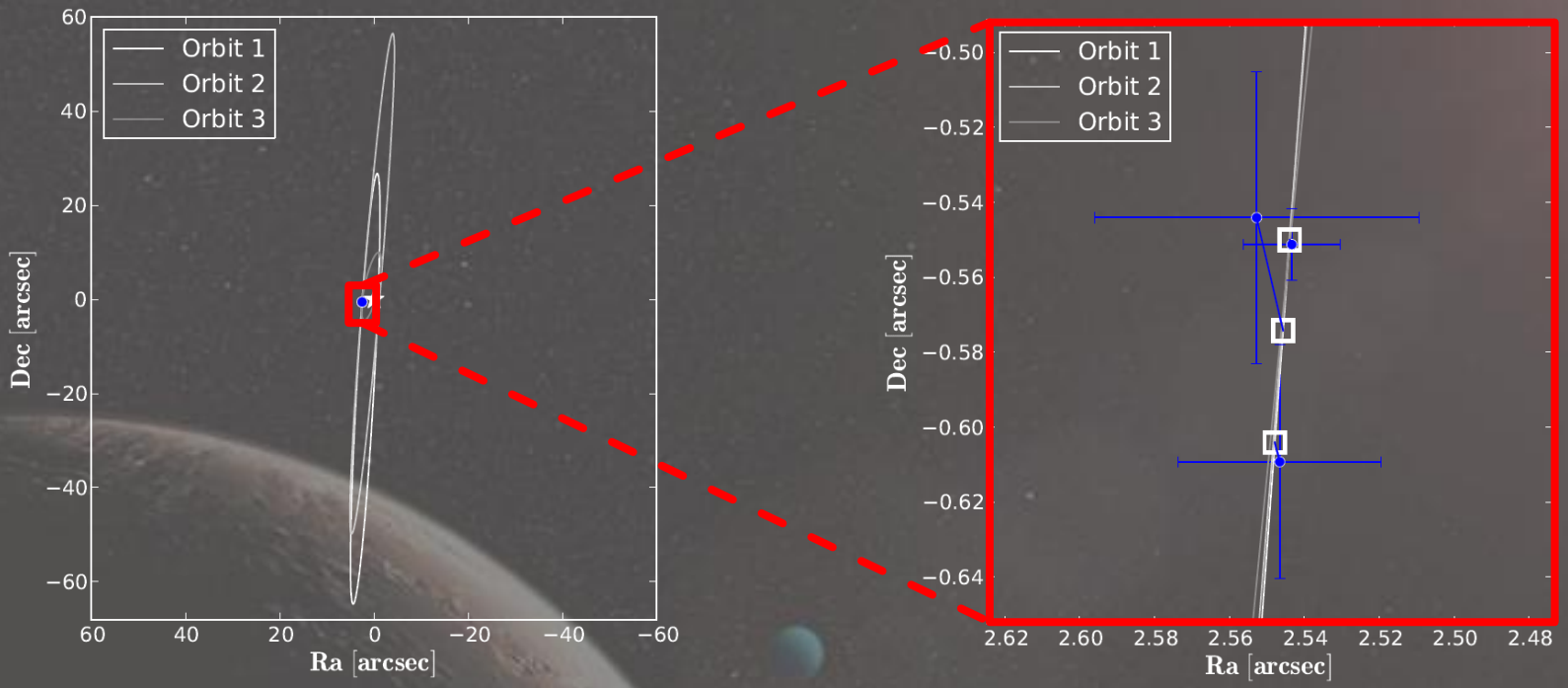
Results - HD130948





Ginski et al. 2013, MNRAS, 434, 671

Results - HD130948

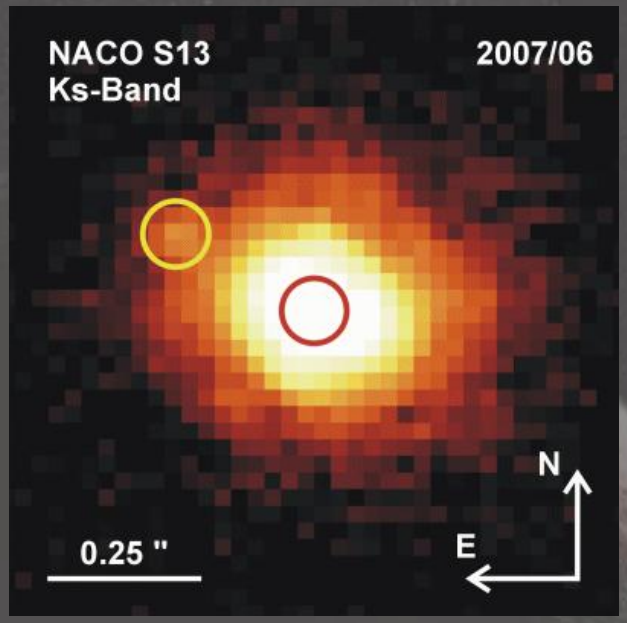


Nr.	1	2	3
a [arcsec]	52.7	57.4	13.4
e	0.61	0.37	0.86
P [yr]	28124.9	31976.4	3590.4
i [deg]	92.2	91.8	96.6
Ω [deg]	177.3	175.3	164.4
ω [deg]	233.7	278.9	282.7
T_0 [JD]	4773615.3	8913552.3	828670.8

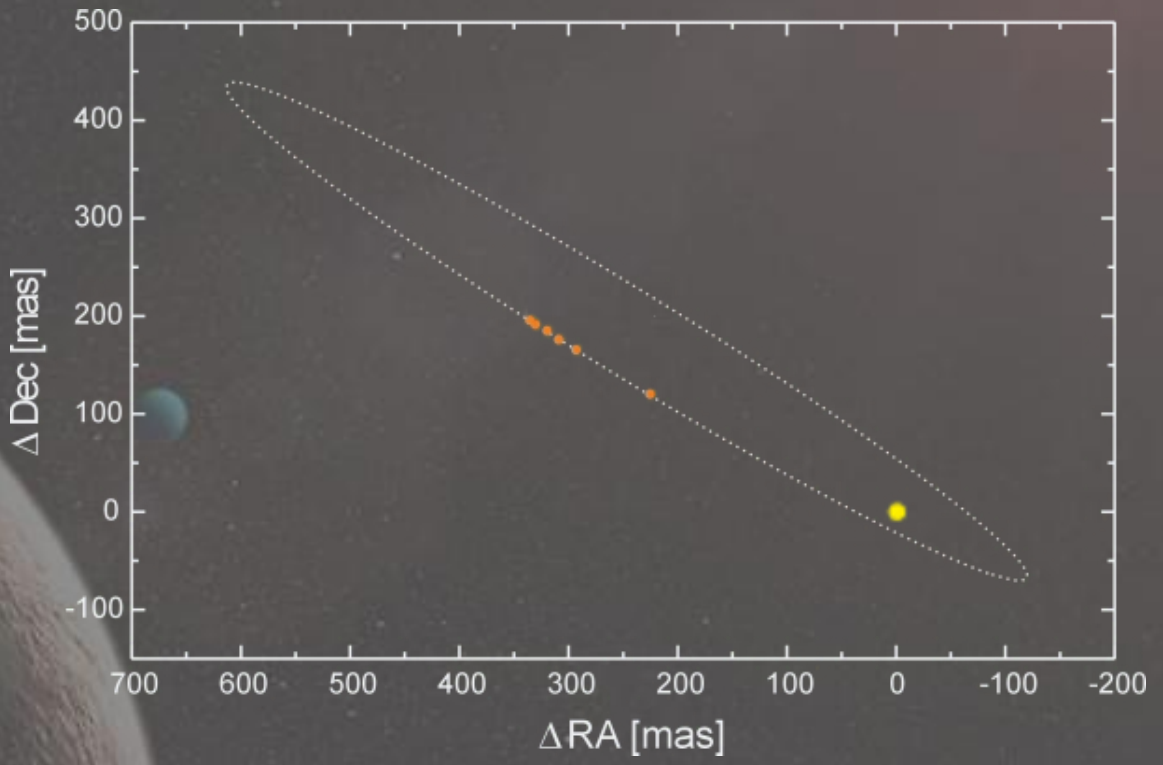
Further Work

Further Work – PZ Tel

Small orbit curvature was detected in the case of the PZ Tel system and the orbit could be constrained well with the LSMC method.



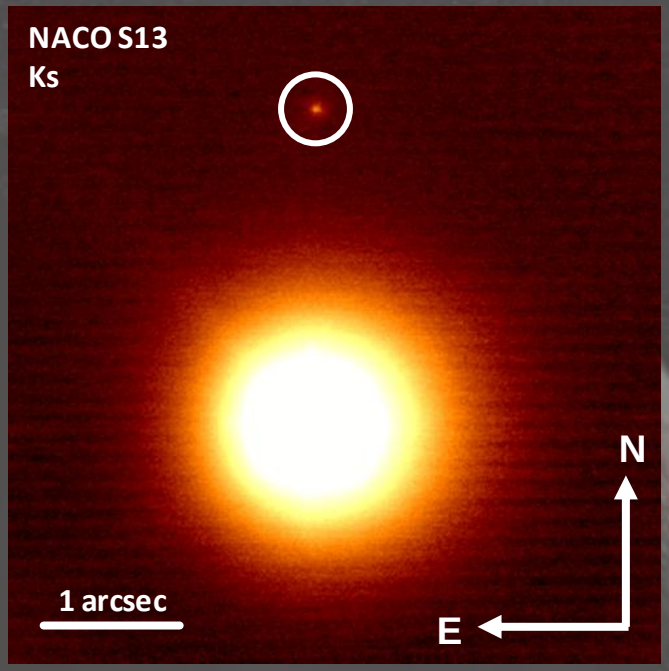
Mugrauer, Röll, Ginski et al. 2012

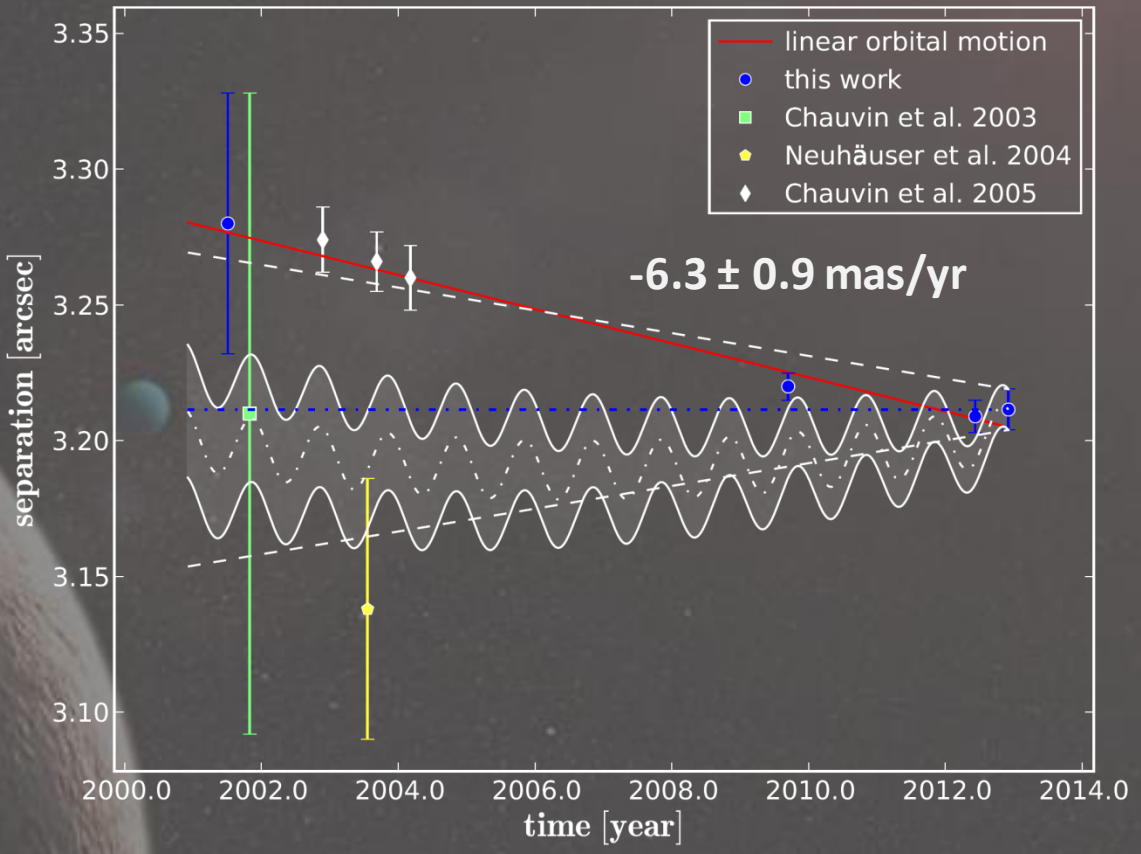


Orbit is highly eccentric with e >0.6 and most likely seen close to edge-on (i between 92° and 110°). Orbit period is a minimum of 64 years but most likely around 114 years.

Further Work – GSC08047

Significant decline of separation detected. Orbits need to be close to edge-on or have e > 0.28 to explain measurements.

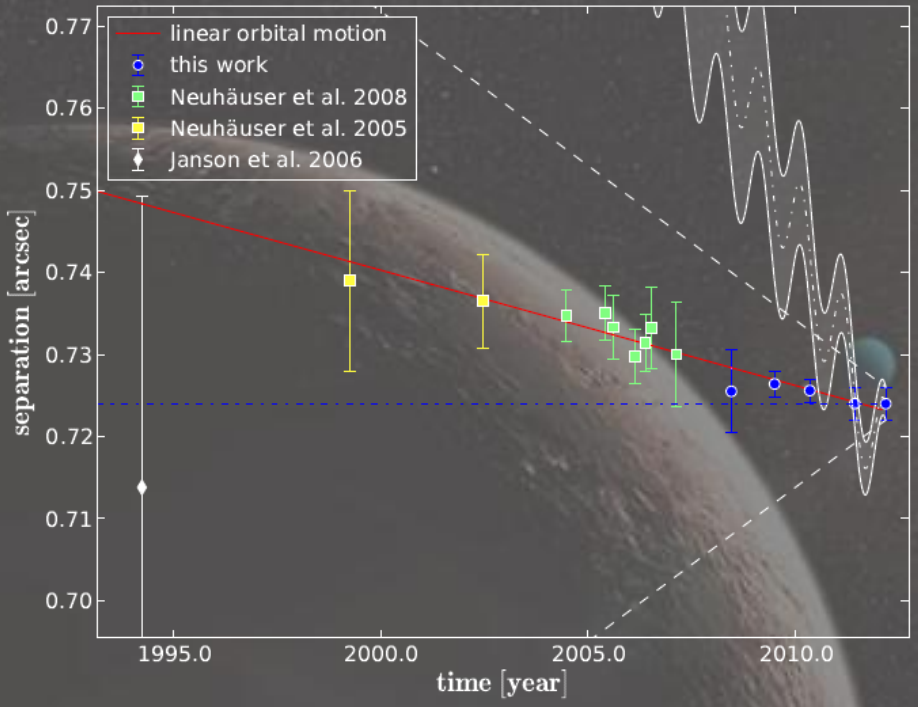


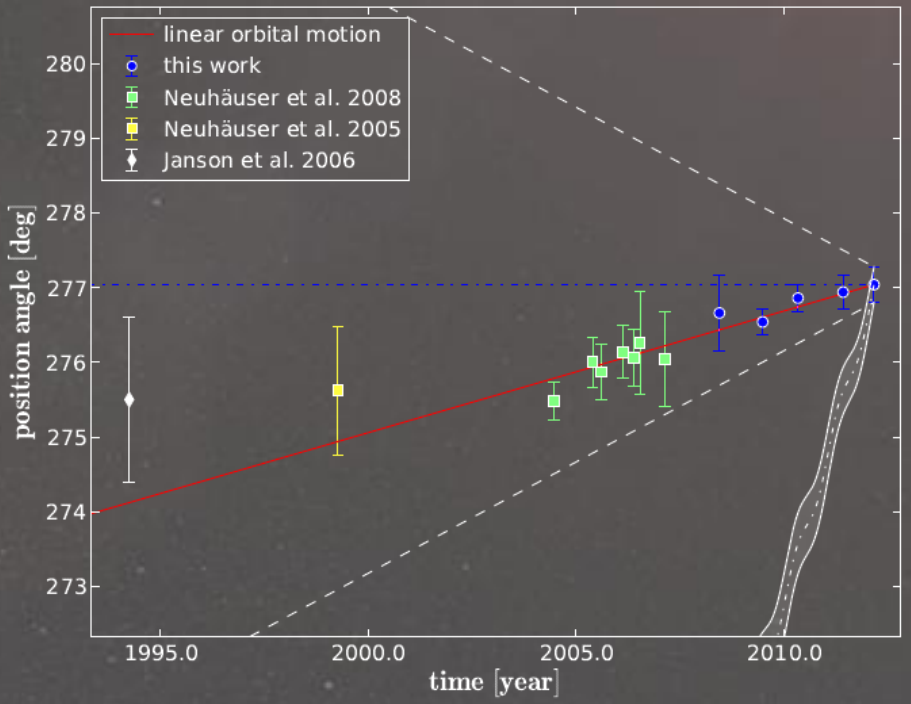


Ginski et al. 2014, MNRAS, 438, 1102

Further Work – GQ Lup

Significant differential motion was detected in separation and position angle of the GQ Lup system.

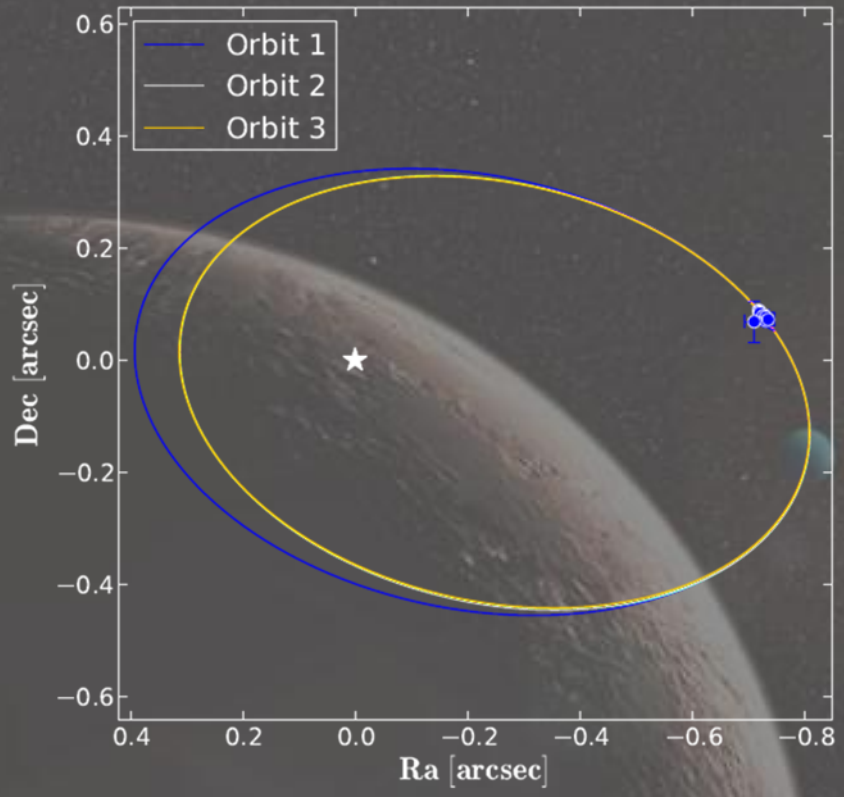


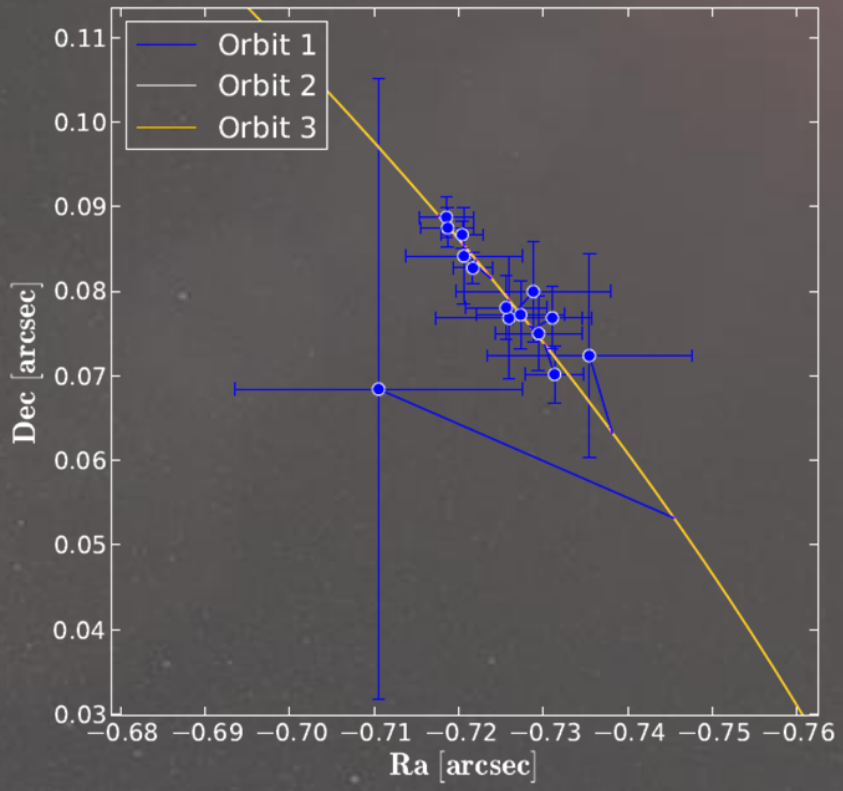


Ginski et al. 2014, in prep.

Further Work – GQ Lup

Preliminary results show best fitting orbits with a ~ 0.6 arcsec (84 au), e between 0.35 and 0.44, and i ~ 45 deg.



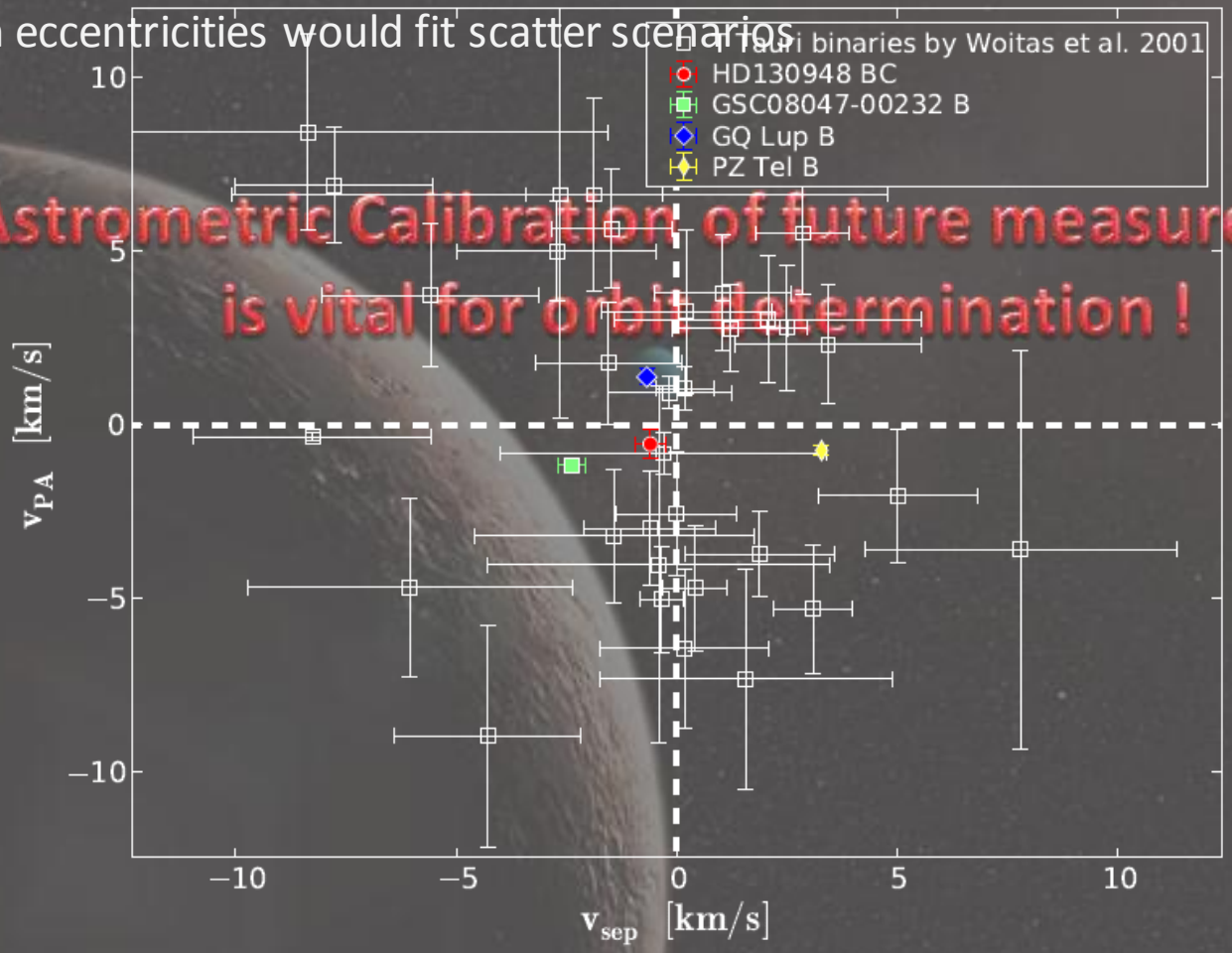


Ginski et al. 2014, in prep.

Conclusions

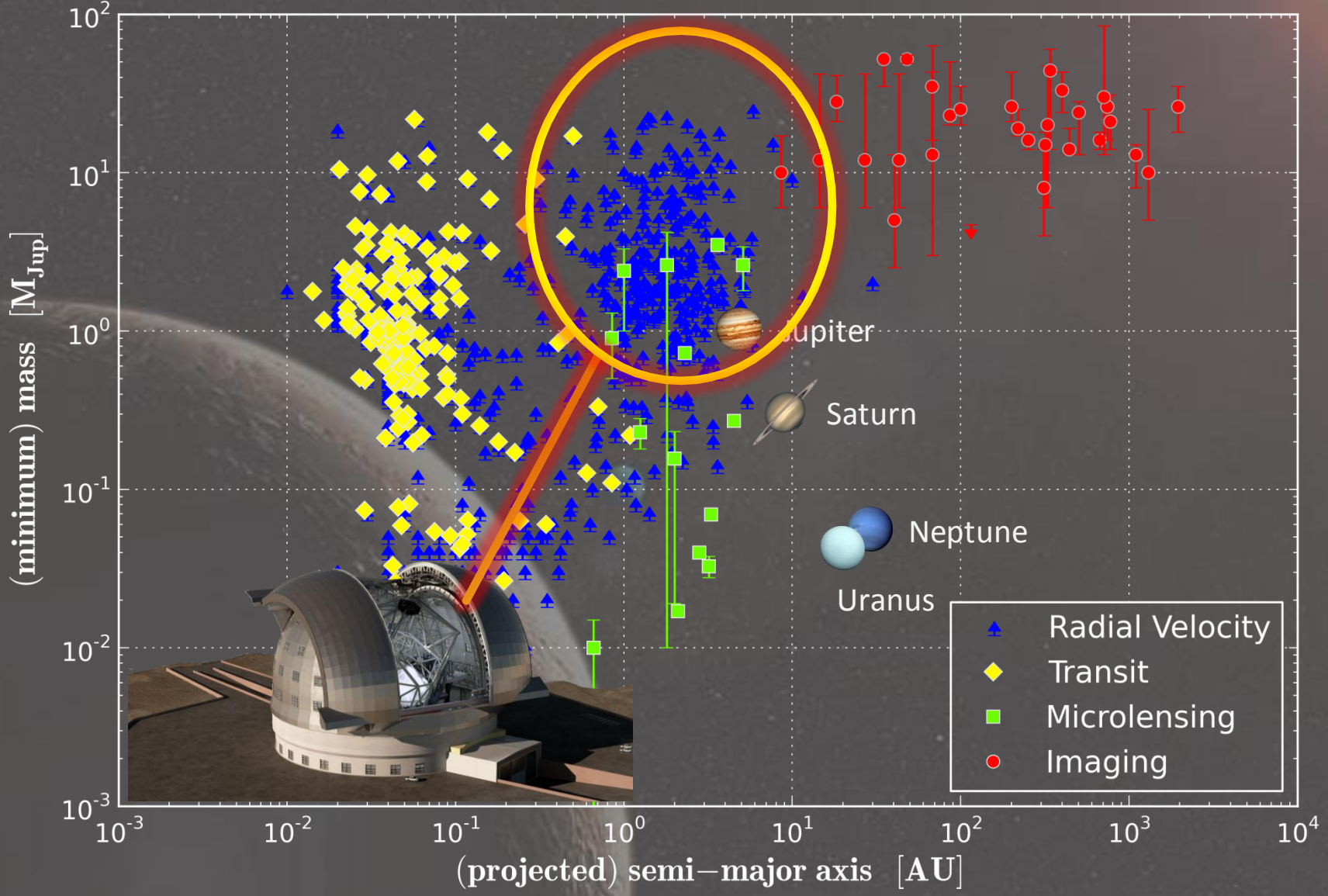
Conclusions

- Common proper motion could be confirmed for all presented companions
- orbital motion was detected but no significant orbit curvature yet
- the detected orbit motion is consistent with low mass objects on wide orbits
- high eccentricities would fit scatter scenarios



Outlook

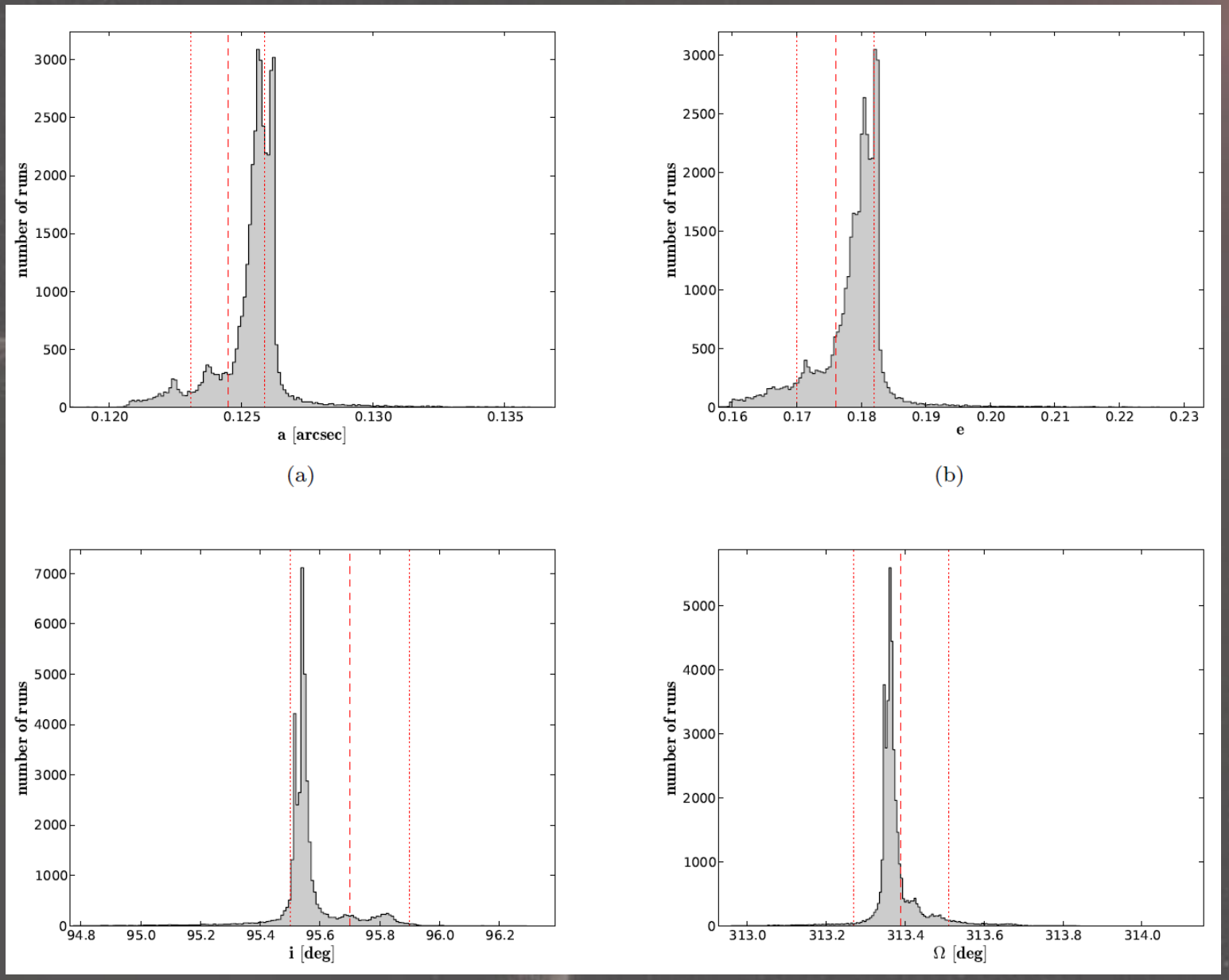
Outlook


(minimum) mass [M_Jup]
(projected) semi−major axis [AU]
Jupiter
Saturn
Neptune
Uranus
Radial Velocity
Transit
Microlensing
Imaging

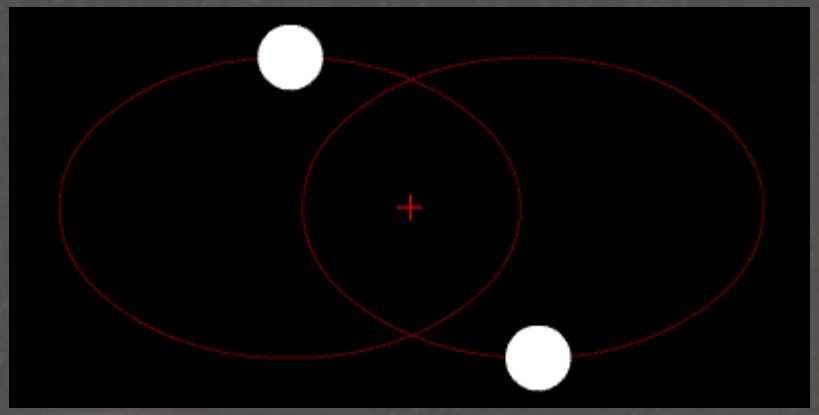

Thanks for your attention !

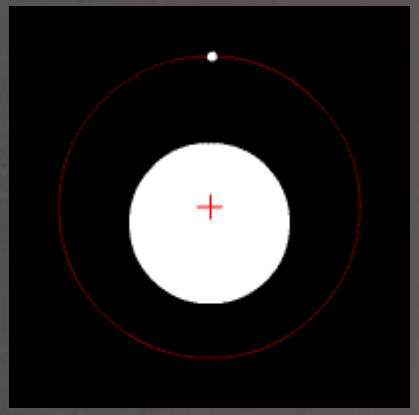
Additional Information

LSMC vs MCMC

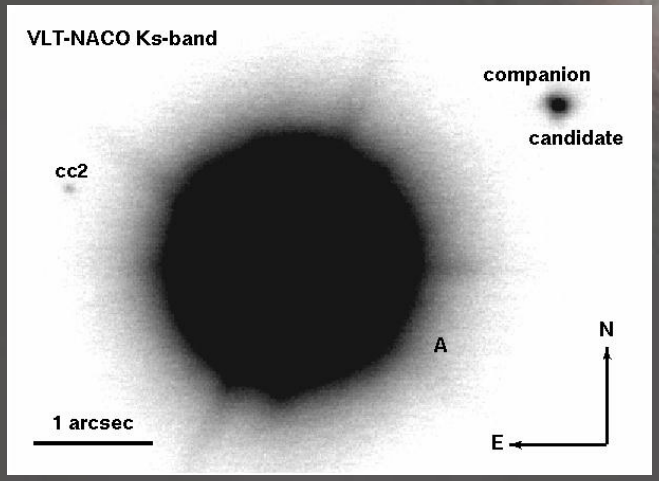

number of runs
a [arcsec]
(a)
number of runs
e
(b)
number of runs
i [deg]
number of runs
Ω [deg]

Absolute Orbits

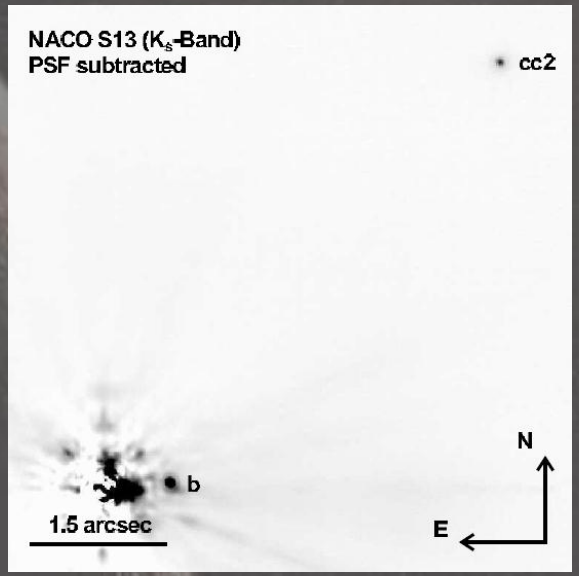




CT Cha by Schmidt et al. 2008



GQ Lup by Neuhäuser et al. 2008



HD203030 by Metchev et al. 2006