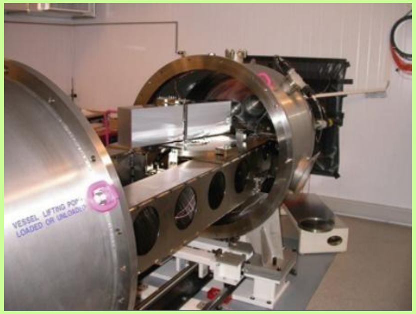
The HARPS-N Opportunity



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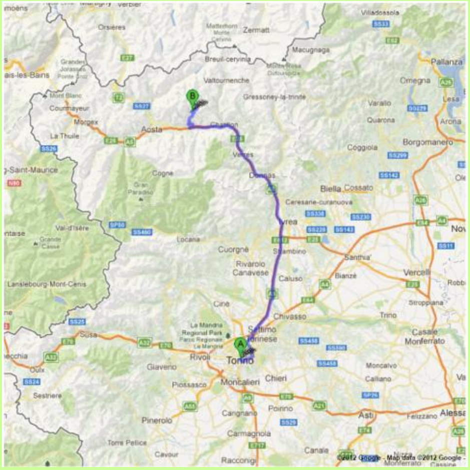
- **GAPS: A long-term programme for the comprehensive characterization of the architectural properties of planetary systems as a function of the hosts' characteristics**

- **GTO: 1) determine densities of terrestrial planets identified by Kepler, 2) look for rocky planets around nearby solar-type dwarfs**

The APACHE Project

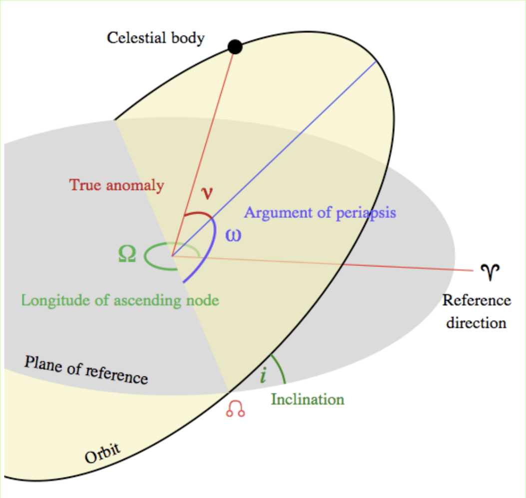


* A quasi-zero km transit search for small-size planets around low-mass stars

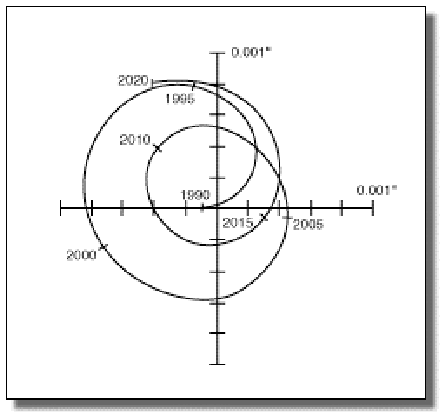
* 5 40-cm telescopes, fully automated operations, lasting five years

* A starting catalog of 3000 bright northern dwarfs

Astrometric Orbits

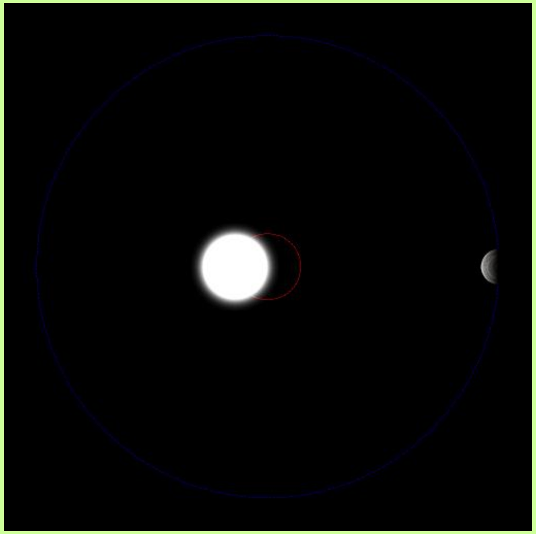


- Astrometry measures stellar positions and uses them to determine a binary orbit projected onto the plane of the sky
- measures all 7 parameters of the orbit, in multiple systems it derives the relative inclination angles between pairs of orbits, regardless of the actual geometry. Mass is derived given a guess for the primary's.
- In analysis, one has to take the proper motion and the stellar parallax into account
- The measured amplitude of the orbital motion (in mas) is:



Astrometric displacement of the Sun due to Jupiter as seen from 10 parsecs.

$$\Delta\theta = 0.5\left(\frac{q}{10^{-3}}\right)\left(\frac{a}{5\,AU}\right)\left(\frac{d}{10\,pc}\right)^{-1}$$



µas Astrometry: Challenges

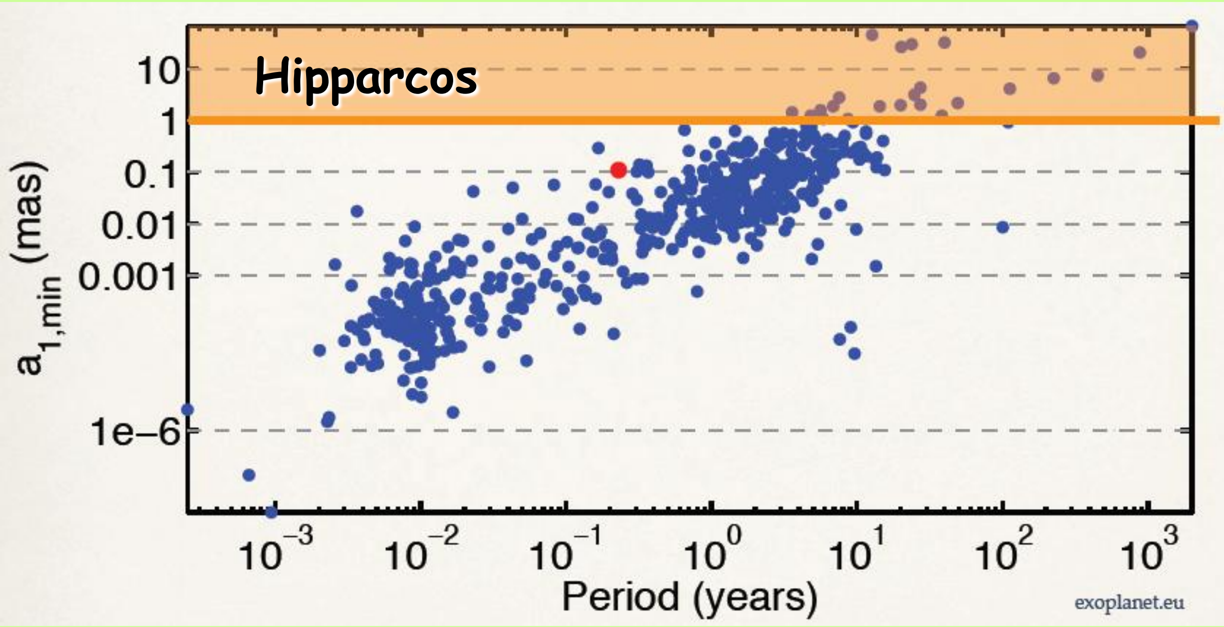


TABLE 1
PARALLAX, PROPER MOTION, AND ASTROMETRIC SIGNATURES INDUCED BY PLANETS OF VARIOUS MASSES AND ORBITAL RADII

Source	α
Jupiter at 1 AU (μas)	100
Jupiter at 5 AU (μas)	500
Jupiter at 0.05 AU (μas)	5
Neptune at 1 AU (μas)	6
Earth at 1 AU (μas)	0.33
Parallax (μas)	1×10^5
Proper motion (μas yr^{-1})	5×10^5

NOTE.—A 1 $M_\odot$ star at 10 pc is assumed.

Sozzetti 2005

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...05, 2010)

- Narrow-angle, relative astrometry: both from the ground and in space (VLTI/PRIMA,???)

- Global astrometry: only in space (Gaia)

Fitting Planetary Systems Orbits

- Highly non-linear fitting procedures, with a large number of model parameters (at a minimum, N_p=5+7*n_{pl}, not counting references)
- Redundancy requirement: $N_{obs} >> N_p$
- Global searches (grids, Fourier decomposition, genetic algorithms, Bayesian inference +MCMC) must be coupled to local minimization procedures (e.g., L-M)
- For strongly interacting systems, dynamical fits using N-body codes will be required