ESPRI: Exoplanet Search with PRIMA at the VLTI

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Summary

- Astrometric detection of the reflex motion of the parent star (motion in plane of sky)
- Around nearby stars this gives better sensitivity to planets in Earth-like orbits than radial-velocity surveys, and can detect planets in face-on orbits
- Allows the precise mass of planets to be determined, without the $\sin(i)$ ambiguity
- Uses VLTI/PRIMA to compare positions of two stars with small angular separation

Science goals

The ESPRI project will look at three main target groups:
Nearby stars (15 pc) – sensitive to planets of > than Uranus-mass
Young stars (<300 Myr) – difficult with radial-velocity surveys
Known exoplanet hosts – with astrometric measurements we can determine the $\sin(i)$ ambiguity of known planets and find new planets in face-on orbits or at larger separations from the parent star

Figure 1 shows the detection domain for astrometric measurements with 50 µas accuracy in comparison to radial velocity surveys. We hope to achieve much higher accuracy on most targets (up to 10 µas accuracy).

Method

The ESPRI project will detect the presence of extrasolar planets from the reflex motion of the parent stars, measured as a change in position on the sky relative to a reference star which has a small angular separation on the sky from the target. These measurements will be based on the phases of complex visibilities measured with the dual-feed VLTI/PRIMA interferometer.

Although atmospheric turbulence disrupts interferometric phases (see *Interferometry Theory* – Haniff, *Theory of Phases* – Berger), accurate astrometry can still be performed between targets which have a small angular separation. This is because of the isoplanatism of the Earth's atmosphere – for small separations the atmospheric phase variations are similar. In practice, what is measured is the cross-visibility ($V_\times$), the product of the complex visibility measured for one star (V_{PS}) and the conjugate of the complex visibility (V_{SeS}) for the second star: $V_\times = V_{PS} V_{SeS}^*$.

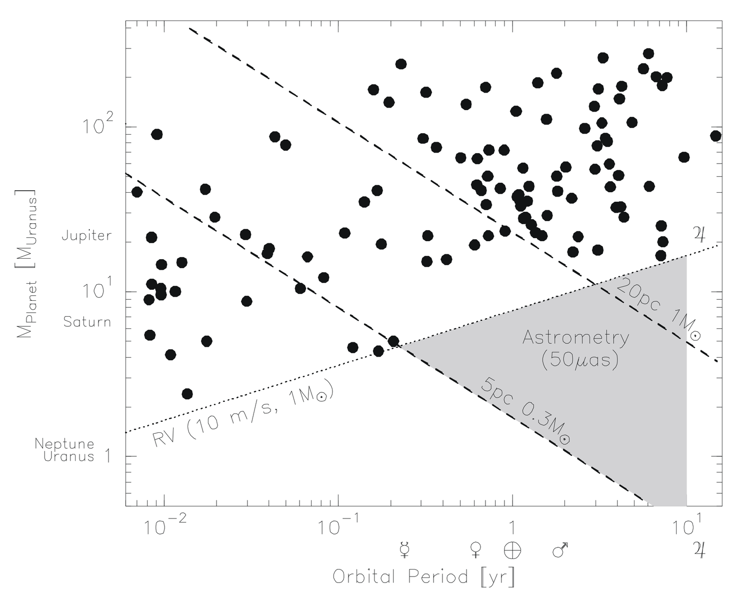

Figure 1 – detection domain for 50 µas astrometric measurements, highlighting the region which is not accessible to the radial velocity technique. The 10 µas accuracy provided by PRIMA will further increase the detection space.

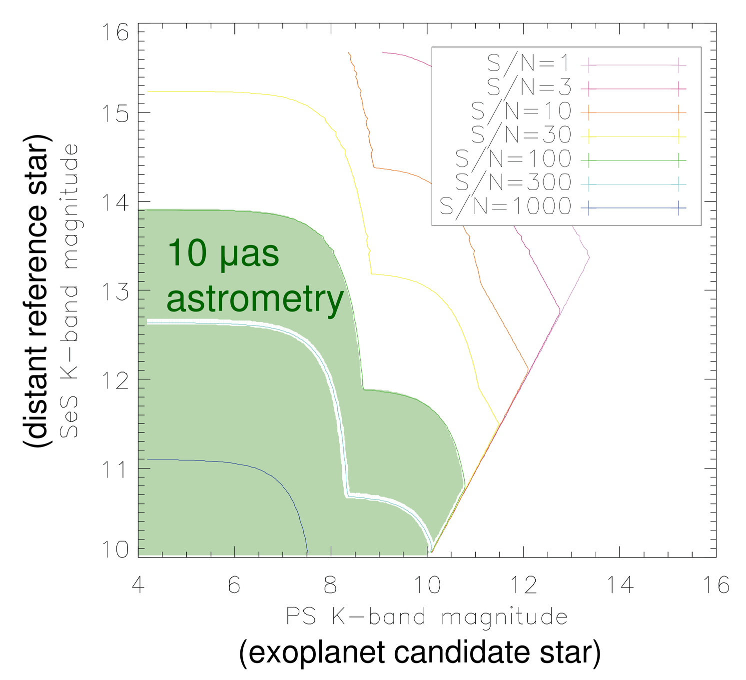

Figure 2 – limiting magnitude (green) of the PRIMA instrument for 10 µas astrometric accuracy in 30 mins, assuming 1.1% of K-band photons entering the ATs are detected, and 10 as ref. star separation.

Expected performance

Figure 2 shows the expected signal-to-noise ratio (SNR) for the cross-visibility ($V_\times$) in a 30-minute integration on a exoplanet target-star/reference-star pair. The SNR is strongly dependent on the reference-star magnitude, as this is generally the fainter of the two stars. For the those few targets which are too faint for hardware fringe-phase tracking, hardware group-delay tracking will be used, and fringe phases will be reconstructed in software post-processing.

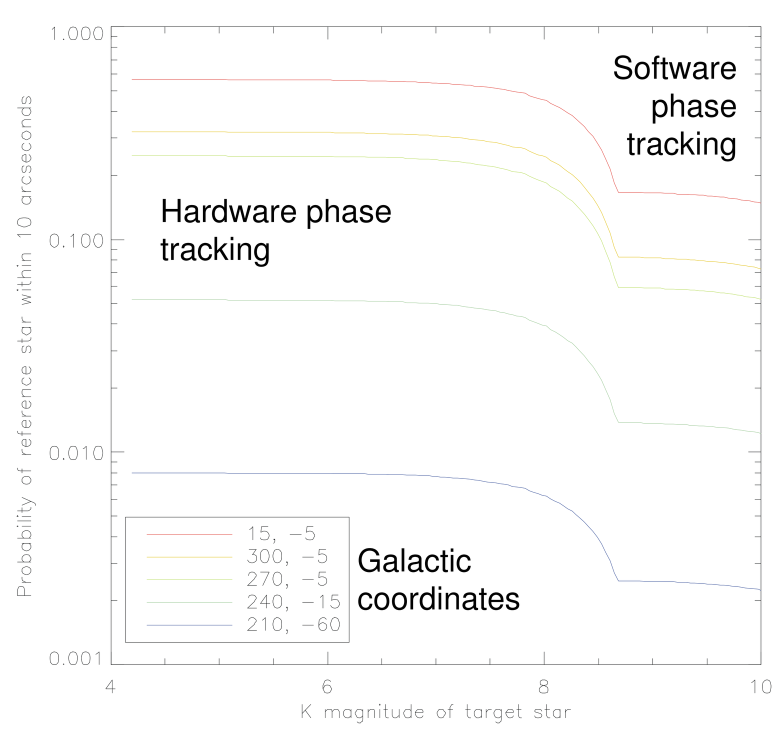

Figure 3 – probability of finding a reference star bright enough to reach 10 µas astrometric accuracy in 30 mins as a function of target galactic coordinates and magnitude, based on data shown in Figure 1 and Besancon stellar tables.

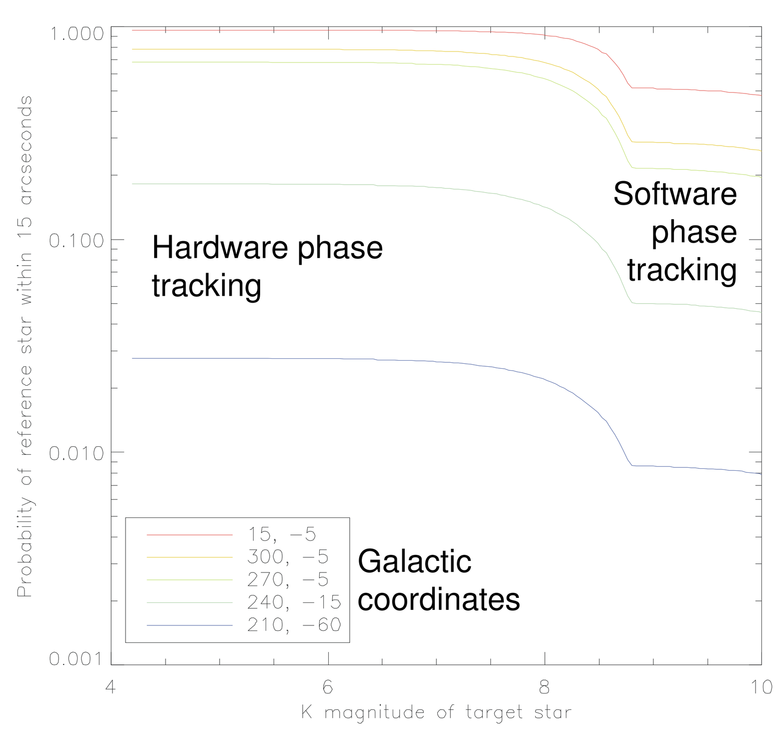

Figure 4 – probability of finding a reference star bright enough to reach 20 µas astrometric accuracy in 30 mins or 10 µas astrometric accuracy in 120 mins – note that reference stars can be both fainter and more distant than in Figure 3.

Preparatory observations

With VLTI/PRIMA we are only able to accurately compare the positions of stars which are close to each other on the sky. Exoplanet-host candidates are only suitable for the ESPRI project if there is a sufficiently bright reference star within 10-15 arcseconds. The probability of finding a reference star suitable for 10-µas astrometry is shown at a range of galactic coordinates in Figure 3. Most of our potential targets are brighter than K=8, allowing hardware fringe-phase tracking – otherwise the fringe phase can be reconstructed in software post-processing. In the galactic plane there is a good probability of finding a reference star. It is easier to find suitable reference stars if only 20-µas accuracy is required or longer integrations are possible (Figure 4).

The ESPRI consortium is now taking K-band images of all potential targets in order to select those targets with suitable reference stars for high-precision narrow-angle astrometry.

ESPRI consortium

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ESO oversees and operates the VLTI and its instruments, and provides advice and support for ESPRI