Search for substellar companions with high precision relative astrometry

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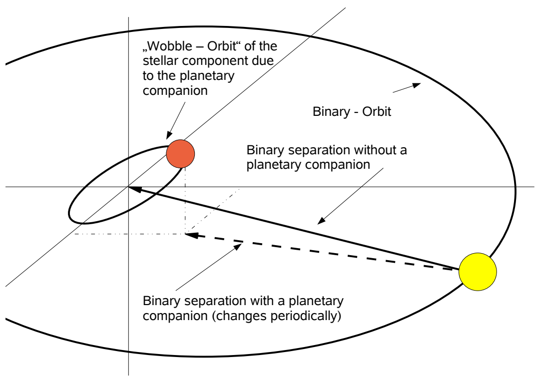
We search for substellar companions (extrasolar planets and brown dwarfs) in stellar multiple systems using high precision relative astrometry with AO assisted ground based and single aperture observations. A substellar companion orbiting its host star will induce a periodic movement of the star due to its orbital motion around their common center of mass.



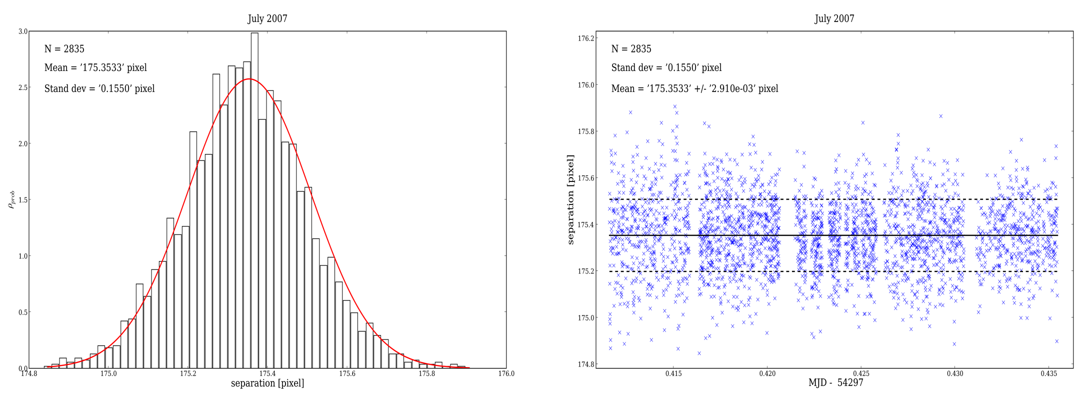
This periodic movement (called "wobble") of the host star yields the orbital information and hence the true mass of the unseen substellar companion. The amplitude of the "wobble" depends on the masses of host star and planetary companion and on the orientation of the stellar and planetary orbit. Due to the very small amplitudes in the case of an unseen extrasolar planet and the missing of absolute calibration frames for the micro-arcsecond level, we measure the wobble indirectly as a periodic change in the relative alignment (separations and position angles) of all stellar members in a multiple system. By measuring these relative changes in the alignment of the stellar multiple system, we are able to reconstruct the "wobble-orbit" of the host star. To reach the required relative precision we take thousands of frames and do statistics.

After a verification of normal distributed measurements, the error of the mean can be calculated as the standard deviation divided by the square root of the number of measurements ($\Delta_{mean} = \sigma/\sqrt{N}$). With this method we achived a measurement error of about $40\,\mu as$ for our measurement of the stellar binary HD 19994 in 2007 (for NACO S13 camera with a given pixel scale of 13.25 mas/pixel).

Additional to the measurement error, we have to take into account the calibration errors. We do not need an absolute calibration, but we have to check for possible changes in the pixel scale and in the position angle of the instrument. To monitor for possible changes we observe a globular cluster additionally to our multiple systems. The relative alignment of all cluster members should be (within an intrinsic error regime due to a transversal velocity dispersion) constant.

Astrometric follow up observations of radial velocity planet candidates are very important. Due to the unknown inclination angle, all masses derived from radial velocity measurements are lower mass limits. Astrometry in contrast can yield the full orbit of the unseen companion and hence its true mass. Even in the case of an astrometric non-detection, we can specify an upper mass limit, which depends on the achieved precision. Furthermore, by searching for planets in multiple systems, we can compare the inclination angle of the planetary and the stellar orbit. Hence, this search program is also a test for the Kozai-effect and the coplanarity of planetary orbits in binary stars.

Using the old globular cluster 47 Tuc (transversal velocity dispersion was determined by Mc Laughlin et al. 2006) to monitor the astrometric stability of the instrument we achieved in total (measurement and calibration error) a relative precision for the stellar binary HD 19994 of about $150\,\mu as$ per epoch, sufficient to detect a substellar companion.



Separation measurements of the binary HD 19994.

HD 19994A is known to have a radial velocity planet candidate with $M\,\sin i = 1.7\,M_J$ (Mayor et al. 2004).