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# An Adaptive Optics Survey for Companions to Stars with Extra-Solar Planets

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**Abstract.** We have undertaken an adaptive optics imaging survey of extra-solar planetary systems and stars showing interesting radial velocity trends from high precision radial velocity searches. Adaptive Optics increases the resolution and dynamic range of an image, substantially improving the detectability of faint close companions. This survey is sensitive to objects less luminous than the bottom of the main sequence at separations as close as 1″. We have detected stellar companions to the planet bearing stars HD 114762 and Tau Boo. We have also detected a companion to the non-planet bearing star 16 Cyg A.

## 1. Introduction

The Lick Adaptive Optics System is a Shack-Hartmann Laser Guide star AO system on the Lick Observatory Shane 3m telescope at Mt Hamilton, California (Max et al. 1997). For these observations, we used the system in natural guide star mode, with the bright star serving as wavefront reference. Under good conditions, the system produces diffraction limited images (0.″15 FWHM) with a strehl ratio of 0.7 in the K band (2.2 $\mu$m).

The AO system feeds a 256×256 pixel infrared camera, IRCAL (Lloyd et al. 2000), which reimages the field of view at 0.″076 per pixel. The camera incorporates a cold focal plane with an occulting finger to obtain high dynamic range images. For this program, we typically take a few minutes of integration of unsaturated images to obtain coverage close to the star, and deep exposures in coronagraphic mode to detect faint companions at larger separations.

We have selected targets from those stars with radial velocity planets, or with radial velocity trends from the Lick and Keck radial velocity surveys.

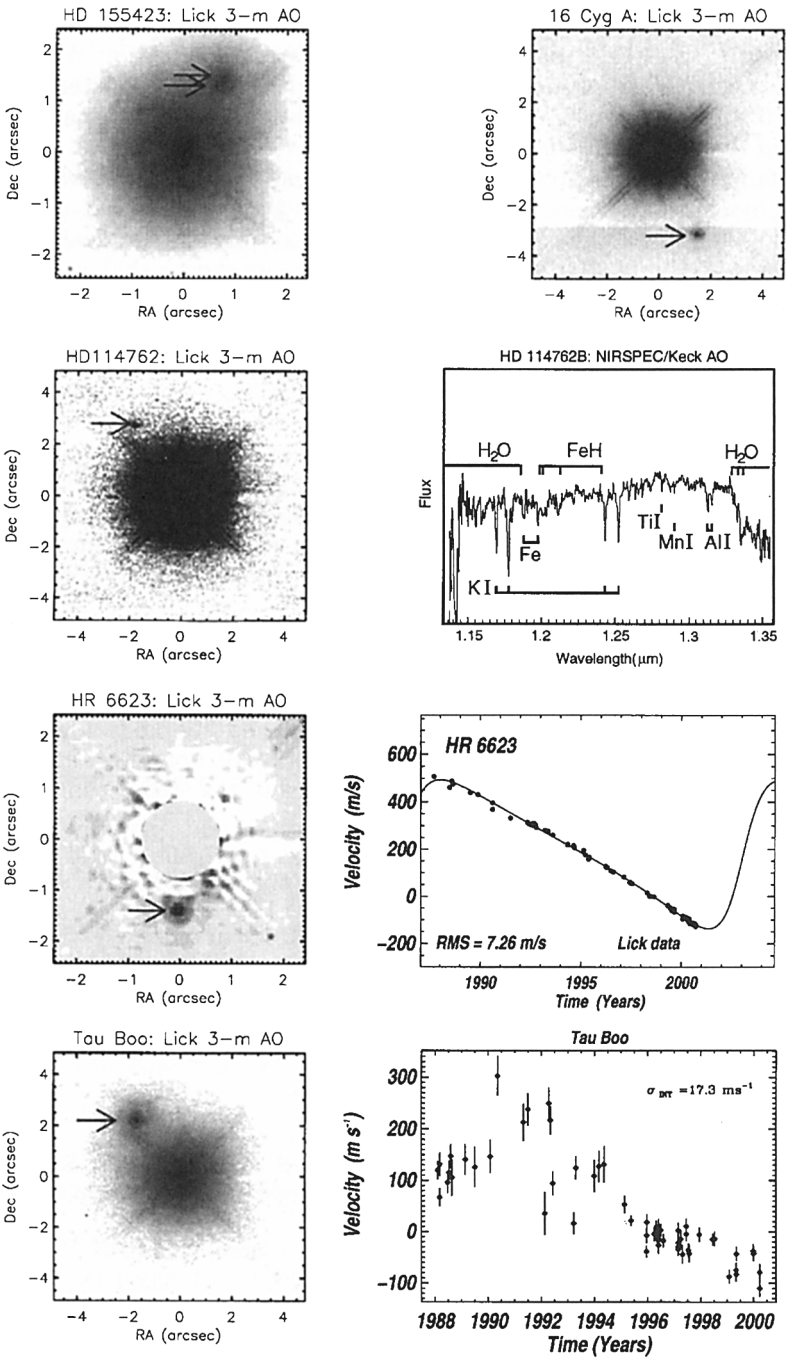


Figure 1. K band images of stars with detected companions; J band spectra of HD 114762B; Radial Velocity data for HR 6623 and Tau Boo (residual)

## 2. Results

HD 155423 (see Fig 1) shows substantial scatter in precision radial velocity measurements. High resolution imaging shows HD 155423 is a hierarchical triple, with a 0.″2 close binary (8AU projected separation) M3 dwarf pair, separated 1.″5 from the F8 dwarf primary.

A faint object was previously discovered near 16 Cyg A, but was not known to be physically associated (Hauser & Marcy 1999). We have confirmed by proper motion measurements that the $\Delta$K=5.4 object is a physically associated M5 dwarf (see Fig 1). Radial velocity measurements show a shallow linear trend.

HD 114762 has a radial velocity companion with an 84 day period and $M \sin i$=11 $M_{Jup}$ (Latham et al. 1989). We have detected a $\Delta$K=7.3 companion 3.″3 from the primary (see Fig 1). *JHK* photometry and follow up Keck AO/NIRSPEC spectroscopy (McLean et al. 2000) reveal the companion to be a late M subdwarf. The physical association of this companion is confirmed by proper motion over a 2 year baseline (Patience et al. 1998).

Radial velocity measurements of HR 6623 show a nearly linear trend over 13 years (see Fig 1). This would classify this object as a poorly determined single lined spectroscopic binary. AO imaging resolves the companion, which is an M5 dwarf. Further radial velocity and astrometric observations will allow accurate mass determinations.

Tau Boo hosts an $M \sin i = 3.9$ $M_{Jup}$, 3.3 day period planet, and shows radial velocity residuals (see Fig 1). It has an M2V companion that was discovered in 1849 at 10.″3. At present it is at 2.″82, with 0.″01 per year of orbital motion. Although it has been suggested that there may be additional companions in the system (Wiedemann, Deming, & Bjoraker 2000), we do not detect any additional companions, and attribute the velocity residuals to the stellar companion.

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