A CORONAGRAPHIC IMAGING SEARCH FOR PLANETARY MASS COMPANIONS TO NEARBY YOUNG STARS USING THE NEAR INFRARED CAMERA ON THE HUBBLE SPACE TELESCOPE.

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A search of 116 nearby young stars has been carried out in Cycle 13 with the *Hubble Space Telescope* using the Near Infrared Camera and Multi Object Spectrograph (NICMOS). Camera 2 coronagraphic observations with the F160W (H band) filter, utilizing the roll subtraction technique to remove the science target point spread function, provide companion sensitivity below the deuterium burning limit for nearly all targets at separations as close as $0.''7$ from the center of the coronagraph. Several candidate planetary mass and substellar companions have been identified, as well as two confirmed common proper motion companions with masses $< 10\ M_{Jup}$.

Direct Imaging Versus Other Techniques

Direct imaging searches for extrasolar planets offer the clear advantage that spectrscopic follow up is possible upon confirmed detection. Indirect techniques such as astrometry, microlensing, transits, and precise radial velocity monitoring can glean a wealth of data on the frequencies of extrasolar planets, their sizes, masses, and in a few exceptional cases, some weak spectral features [1,2,3,4,5]. However, only direct detection allows investigation into the atmospheric compositions and spectral energy distributions of extrasolar planets.

Current and planned ground based adaptive optics and space based facilities are capable of both imaging and spectroscopy of nearby young (~ 10 Myr) companions with masses below the deuterium burning limit. Howver, in the discovery phase of any survey for planetary mass companions, HST / NICMOS is superior because of the demonstrated stability of the instrument and its point spread function, its immunity to weather conditions, and its proven sensitivity.

Young Nearby Stars

The HST / NICMOS search focuses on the closest, youngest stellar groups; the TW Hydrae Association ($d \sim 60$ pc, $\tau \sim 8$ Myr), the β Pictoris moving group ($d \sim 35$ pc, $\tau \sim 12$ Myr), the Tucana/HorA group ($d \sim 45$ pc, $\tau \sim 30$ Myr), and the AB Doradus group ($d \sim 20$ pc, $\tau \sim 50$ Myr). The ages of these young nearby stellar groups are well determined using multiple indicators such as color-magnitude relations, lithium line strength, x ray emission, Galactic UVW space motion, stellar rotation, emission lines, etc. [6,7,8,9,10,11]. These targets were chosen for the following reasons: (1) proximity to the Earth allows detection of companions with smaller orbital semimajor axes, important for probing regions analogous to the orbits of Uranus and Neptune, and implies higher flux from faint candidate companions relative to more distant systems; (2) youth means that any self luminous planetary mass

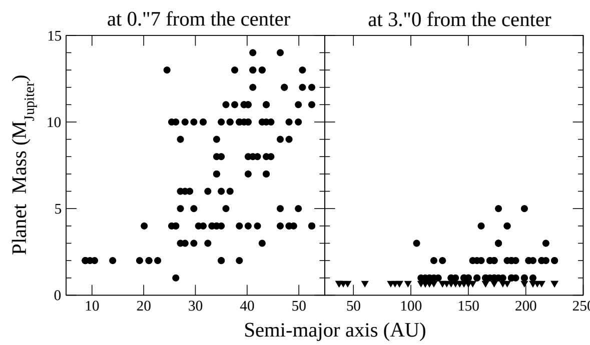

Figure 1: Individual sensitivity to planetary mass companions for each of the 116 targets based on their known distances and ages. For both $0.''7$ and $3''.0$ from the coronagraphic center, the x axis plots the projected separation in AU, while the y axis plots the mass sensitivity in M_{Jup}, using the models of [12], for $\Delta H \approx 11$ mag and ≈ 15 mag respectively.

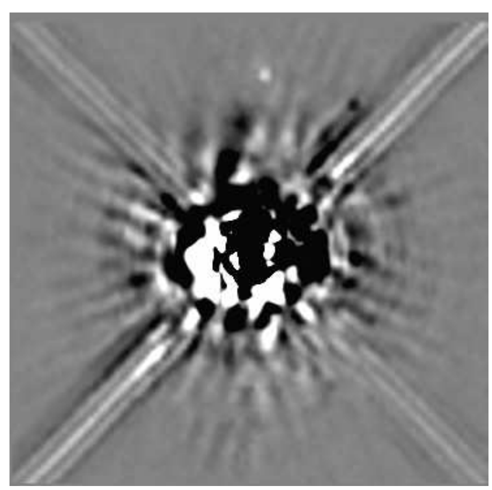

Figure 2: Target with a candidate companion at $2.''6$ from the center of the coronagraph and $H = 19.6$ mag. If physically associated, this object would have an absolute magnitude comparable to the latest known T dwarfs ($T_{\rm eff} \approx 750$ K) and $M \approx 2\ M_{Jup}$ at an age of 10 Myr [12,13].

objects will be significantly brighter than their older counterparts; (3) the ~ 10 Myr age regime corresponds to the epoch for gas giant planet formation in the Solar system; (4) these stellar groups are well studied and have known ages, hence estimating masses for confirmed companions should be straightforward.

Sensitivity to Planetary Mass Companions

The stability of the HST / NICMOS coronagraphic point spread function allows the roll subtraction technique to yield faint companion detectability of $\Delta H \approx 11$ mag at $0.''7$ and $\Delta H \approx 15$ mag at $3.''0$ separation from the center of the coronagraph [14]. Applying these approximate limits to the 116 sample stars, and comparing the resulting H band sensitivities with the absolute H magnitudes expected of young low mass objects using the models of [12], yields the expected mass sensitivity for each target star. Figure 1 plots the (approximately) lowest mass companion expected to be detectable around each target star at these two separations based on its known distance and age. As is clear from the figure, objects below the deuterium burning limit ($\approx 13\ M_{Jup}$) are detectable around over 90% of the target stars at $0.''7$, and objects with masses below 5 M_{Jup} are detectable around over 90% of the target stars at $3.''0$.

In Figure 2 is shown a target star with a candidate companion at $2.''6$ separation with $\Delta H = 12.7$ mag. The image is a subtraction of two images taken at different spacecraft roll orientations, i.e. a roll subtraction. This is an excellent example of the point spread function stability and sensitivity of HST / NICMOS; this object has a signal to noise ratio greater than 7 in the roll recombined image. If the pair are gravitationally bound, the candidate companion would be a T dwarf with a mass well below the deuterium burning limit.

Ongoing Work

In order to confirm or rule out physical association for the several candidate planetary mass and substellar companions found in the study, ground based follow up work is necessary. Specifically, astrometry will allow discrimination of commmon or differential proper motion, while photometric near infrared colors will constrain possible spectral types prior to any follow up spectroscopy.

Ground based adaptive optics imaging follow up is currently being conducted at Gemini Observatory with NIRI / Altair (and soon with NIFS / Altair and NICI / Hokupa'a 85), at Keck Observatory with NIRC2, and at the Paranal Observatory with NACO.

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