Clio: A 5 micron camera for the detection of giant exoplanets

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(see Freed et al. 2004, Proc. SPIE, 5492; available @ caao.as.arizona.edu)

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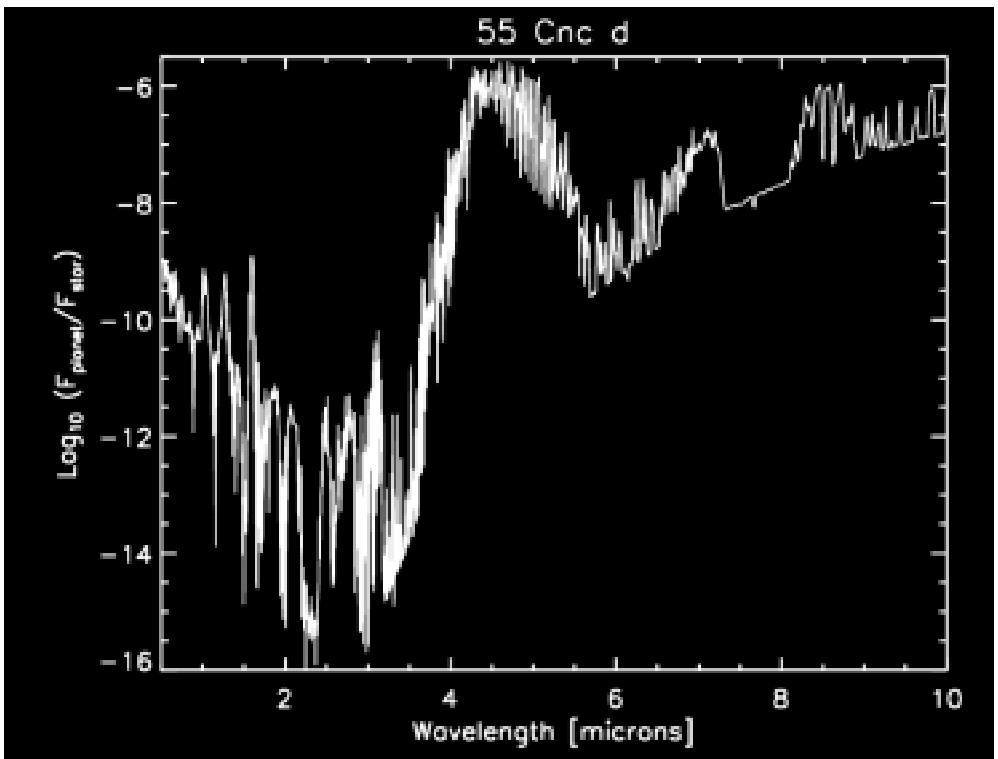
Why are giant exoplanets important in the search for life?

The location, mass, eccentricity, and formation time of giant exoplanets is thought to strongly influence the ability of water-rich terrestrial exoplanets to form. Giant exoplanets that are either too close to the central star, too massive, in very non-circular orbits, or form too early may clear out water-rich planetary building blocks necessary to the formation of Earth-like exoplanets (e.g. Chambers 2003, LPI, 34, 2000). As a result, understanding the frequency of giant exoplanets, as well as their mass and separation distribution functions, will help us understand the frequency of Earth-like exoplanets.

Why a 5 micron camera?

- Objective: Direct imaging of giant exoplanets (>5 $M_{jupiter}$) at Jupiter-like separations (>5 AU)
- Advantages of a 5 micron imager: high Strehl ratio, direct imaging, planetary spectra expected to peak @ 5 μm
- Problems: high and variable background, conventional adaptive optics impossible because of added thermal background
- Solution: The adaptive secondary at the MMT 6.5m telescope, currently in operation, uses *no* extra optics in the science path for the AO.



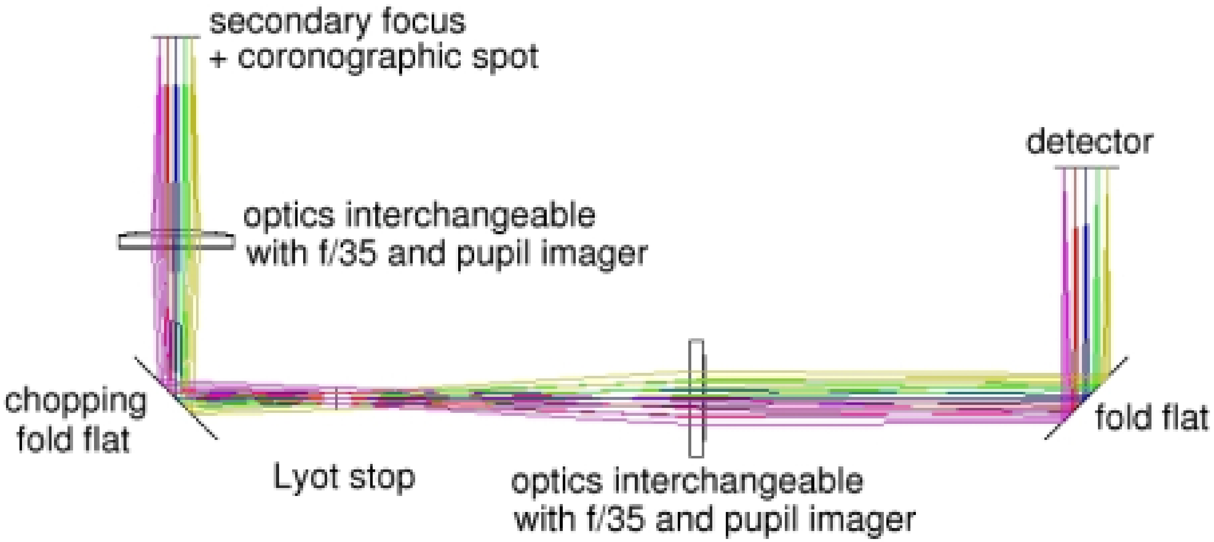
Theoretical contrast spectrum of 55 Cnc d (G8V primary, 5.9AU, M*sini*=4.05 M_J).

Data from Sudarsky, Burrows & Hubeny 2003, ApJ, 588

The 5 micron camera

- 3 channel system
  - → L (3.77 μm) and M (4.68 μm) band channel, f/20, ~Nyquist sampled @ L', FOV=15 x 12"
  - → H (1.65 μm) and Ks (2.15 μm) band channel, f/35, ~Nyquist sampled @ Ks, FOV=8.7 x 7"
  - → pupil imager

- Timeline: Engineering run w/ AO Jan/Feb 2005



Optical drawing of the f/20 channel

Exoplanet Survey

- The expected number of planets detected can be determined from the expected mass and separation distribution functions. This means that, conversely, *the number of detected planets can give an indication of the shape of the distribution functions*.

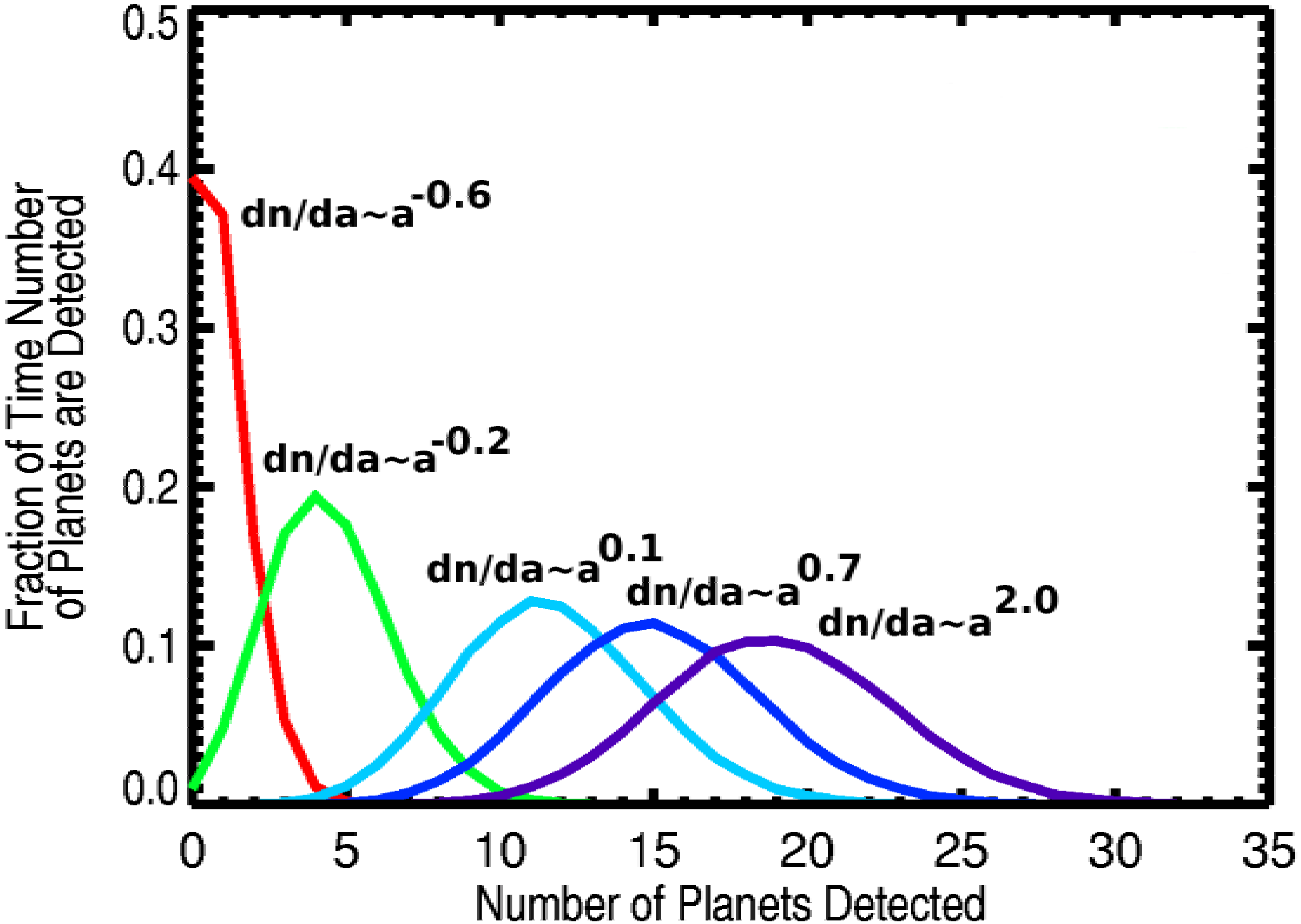
- Radial velocity studies suggest $dn/dM \sim M^{-0.7}$ and $dn/da \sim a^{>0}$ (Marcy et al. 2003, ASP Conf. Ser.). A fit to the data from 0.2 AU $< a <$ 2AU gives $dn/da \sim a^{0.69}$

- We can use the radial velocity results as a first guess to the form of the distribution functions at larger separations. We assume the distribution functions to be valid for 1-15 $M_{jupiter}$ and 0.01-50AU.

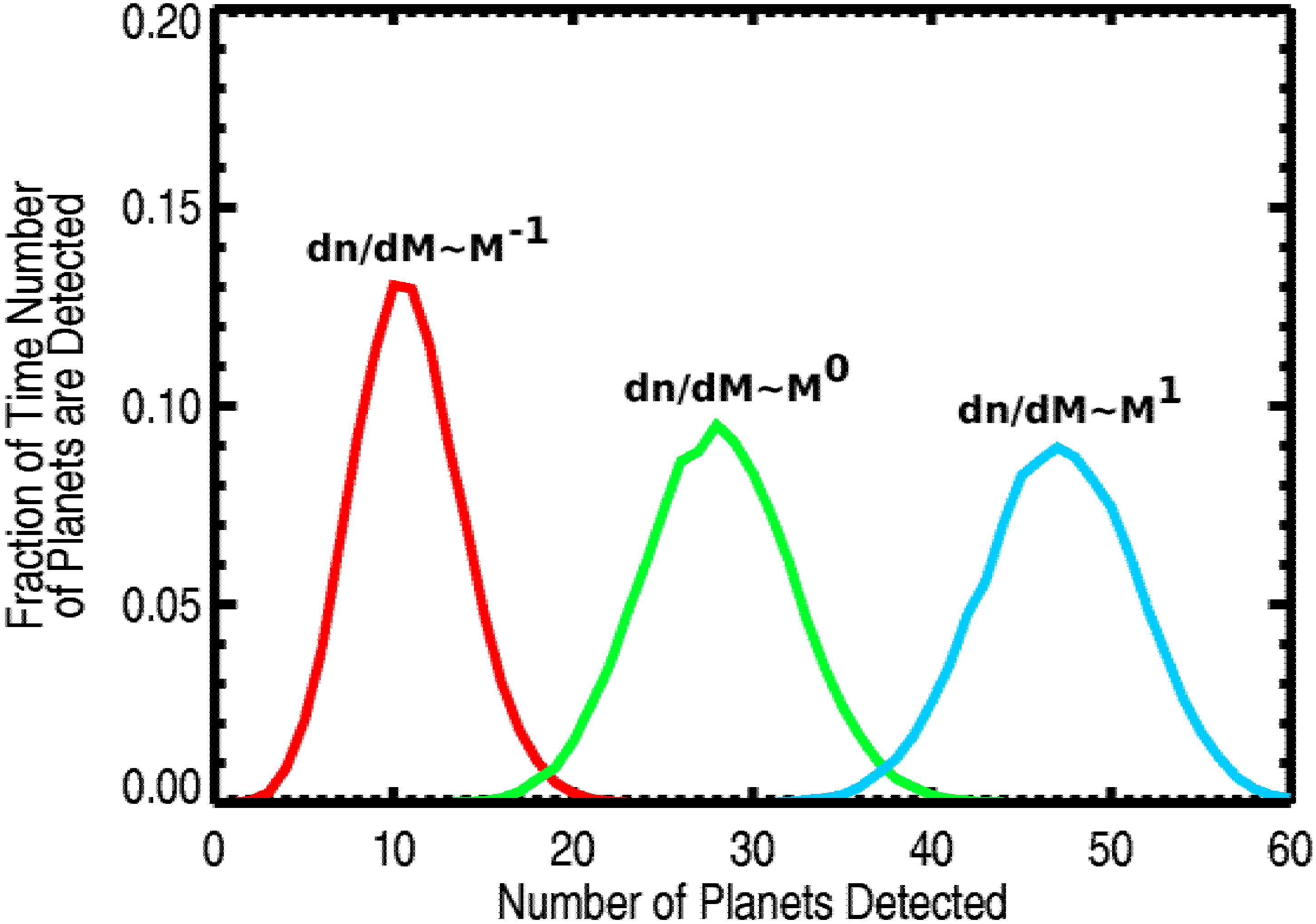
- Estimations of our sensitivities for an optimum filter (CWL=4.75 um BP=0.58um) with 2 hour integrations at the MMT are used (Freed et al. 2004, Proc. SPIE, 5492; available at caao.as.arizona.edu).

- We performed a series of Monte Carlo simulations to determine the number of detectable planets for various distribution functions and define an optimal target sample.
The two figures show the results.

- The survey will consist of 80 nearby (<20 pc) stars in the northern hemisphere less than 1 Gyr old and with spectral types of M0-F0. Assuming $dn/da \sim a^{0.69}$ and $dn/dM \sim M^{-0.7}$ we expect to detect 15 ± 3 companions with 4-15 $M_{jupiter}$ at 17-50 AU.



Fractional chance of detecting various numbers of planets given a mass distribution of $dn/dM \sim M^{-0.7}$ and 5 different separation distribution functions. It appears unlikely that no planets will be detected with this survey. If, indeed, no planets are detected, we should be able to significantly rule out a large parameter space of distribution functions. A null result will rule out $dn/da \sim a^{-0.2}$ at 2σ and $dn/da \sim a^{0.7}$ at 4σ.



Fractional chance of detecting various numbers of planets given a separation distribution function of $dn/da \sim a^{0.69}$ and three different mass distribution functions. All three mass distributions are clearly distinguishable. A null result will rule out $dn/dM \sim M^{-1}$ at 4σ and $dn/dM \sim M$ at 11σ.