How to Directly Image a Habitable Planet Around Alpha Centauri with a ~30-45cm Space Telescope.

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Figure 1. The original "pale blue dot" image of our Earth taken by Voyager.

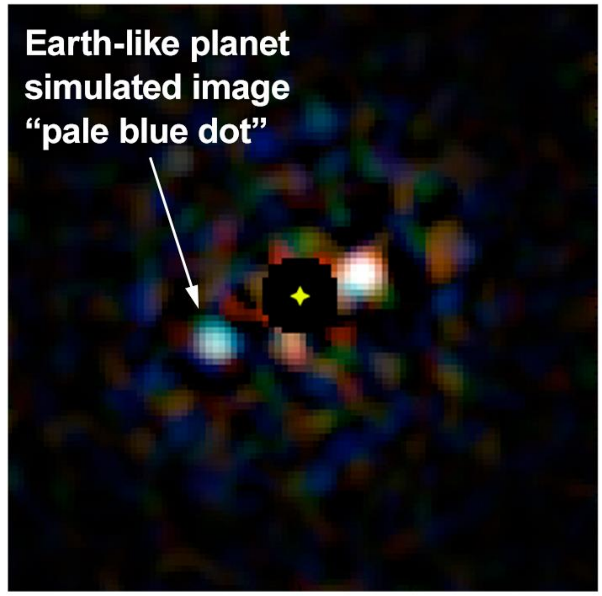

Figure 2. Simulated image of another "pale blue dot": a possible Earth-like planet around Alpha Centauri A. (Venus- and Mars-like planets are also shown.)

In 1990, at the request of Carl Sagan, Voyager 1 turned and took a picture of Earth from a distance of 6 billion kilometers. This produced the famous "pale blue dot" image of our planet (see Figure 1). Several mission concepts are being studied to obtain similar images of Earth-like exoplanets (exo-Earths) around other stars.

Direct imaging enables spectroscopic detection of biomarkers such as atmospheric oxygen and methane, which would be highly suggestive of extraterrestrial life. It is commonly thought that directly imaging a potentially habitable exoplanet requires telescopes with apertures of at least 1 meter, costing at least $1B, and launching no earlier than the 2020s.

A notable exception to this is Alpha Centauri (A and B), which is an extreme and fortuitous outlier among FGKM stars in terms of apparent habitable zone size. Specifically, Alpha Centauri habitable zones span about 0.5-1" in stellocentric angle, ~3x wider than around any other FGKM star. This enables a ~30-45cm visible light space telescope equipped with a modern high performance coronagraph to resolve the habitable zone at high contrast and directly image any potentially habitable planet that may exist in the system. Due to the extreme apparent brightness of the stars, exposure times can be as short as minutes with ideal components, or days with realistic ones. This makes it possible to do color photometry on potentially habitable planets sufficient to differentiate Venus-like, Earth-like, and Mars-like planets from each other and establish the presence of an Earth-pressure atmosphere through fits to a Rayleigh scattering slope.

The raw contrast requirements for such an instrument can be relaxed to 1e-8 if the mission spends 2 years collecting tens of thousands of images on the same target, enabling a factor of 500-1000 speckle suppression in post processing with a new technique called Orbital Differential Imaging (ODI). The light leak from both stars is controllable with a special wavefront control algorithm known as Multi-Star Wavefront Control (MSWC), which independently suppresses diffraction and aberrations from both stars using independent modes on the deformable mirror. This presentation will discuss the challenges involved with direct imaging of Alpha Centauri planetary systems with a small telescope and how the above technologies are used together to solve them.

We also show examples of small coronagraphic mission concepts currently being developed to take advantage of this opportunity, and in particular a mission concept called "ACESat: Alpha Centauri Exoplanet Sattellite" submitted to NASA's small Explorer (SMEX) program in December of 2014.