Optimal Spectrograph and Wavefront Control Architectures for High-Contrast Exoplanet Characterization

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In this proposal, we aim to explore and demonstrate optimal spectrograph and wavefront control architectures for high-contrast exoplanet characterization with future space-based observatories. Once a candidate exoplanet has been detected and its position measured, follow-up spectroscopy over a wide range of wavelengths and spectral resolutions is necessary to characterize its atmosphere in details. According to the most recent Design Reference Missions for WFIRST CGI, HabEx and LUVOIR, the time required for spectroscopic characterization is typically two orders of magnitude larger than for detection. The metrics used to optimize instrument and wavefront control architectures for exoplanet searches are however sub-optimal for follow-up spectroscopy. Indeed, planet searches necessitate large dark holes to be cleared out of residual starlight and put a strain on the wavefront control system that results in contrast, throughput and bandwidth trade-offs. However, once the position of the planet is known, wavefront control degrees of freedom can be re-allocated by reducing the dark hole size and used to improve contrast, throughput and bandwidths, potentially reducing the spectroscopic exposure time by orders of magnitude. Moreover, we recently showed that the use of single-mode fibers to feed the planet light to a single or few-objects spectrograph can also lead to substantial gains in efficiency. Our proposed program will explore the dark hole size, contrast, throughput, and bandwidth trade space in detail by undergoing detailed end-to-end numerical simulations and laboratory demonstrations in the Exoplanet Technology Lab and High Contrast Spectroscopy Testbed at Caltech.