**Clarissa Do O - Research Plan Statement**

        In the past decade, we have discovered many exoplanets, which are planets that orbit stars other than the Sun, through both ground and space-based observation campaigns. We tend to find larger sized planets that are not similar to Earth. However, Earth-like planets are much smaller than their host stars and therefore are hard to detect using present day technology. Highly stable, precise (0.3 m/s precision) fiber-fed spectrographs have the potential to not only allow us to discover Earth-like planets by detecting the Doppler shift caused by the planet’s gravity on its host star, but to also resolve spectral lines that could allow us to analyze the planet’s atmospheric composition. The High-resolution Infrared Spectrograph for Exoplanet Characterization (HISPEC) is a diffraction-limited spectrograph which is currently being developed for the Keck Observatory [[1](https://arxiv.org/abs/1908.03623)] is a pathfinder for the Multi-Object Diffraction-limited High-resolution Infrared Spectrograph (MODHIS), a high precision spectrograph to be installed in Thirty Meter Telescope (TMT) soon after its first light. HISPEC will present extreme advances in instrumentation for astronomy, since it aims for not only very precise spectrograph measurements but also for improvements in the adaptive optics system technologies. Beyond the instrumentation developments, this project will provide useful and innovative data that can help us understand some of humanity’s biggest questions. These questions range from wondering if there are planets that could possibly harbor life in other star systems, to how planetary systems are formed and evolve during a star’s lifetime. To accomplish these goals, spectrographs require several improvements, such as in the wavefront sensing, wavefront control and data processing fields. By improving our current instruments, we may understand more about planetary formation and evolution.

**Intellectual Merit**

         Our current spectrograph technology has the capability to precisely identify spectral lines and radial velocities for exoplanet detection. However, one of the biggest issues in ground-based astronomy is the introduction of wavefront error, which is the deviation of the resulting reflected or transmitted wavefront from its perfect shape due to the light passing through the atmosphere. Wavefront error decreases the amount of light that is coupled into spectrographs, and with that, it decreases the precision of our data. For exoplanet science, we need very precise data in order to detect exoplanets and analyze their atmospheric composition using spectroscopy. **I** **propose to investigate the effect of wavefront error on single mode fiber coupling efficiencies. I will analyze how such errors can be reduced to provide more precision on HISPEC, and to optimize its data reduction algorithm.** This includes three main steps: work on the adaptive optics system to improve our wavefront error prediction, perform simulations to analyze how our single-mode fiber coupling efficiency is changing as our wavefront error changes, and work on HISPEC’s pipeline to provide optimal data extraction. My experiences in the field of exoplanet and instrumentation make this a suitable step during my graduate studies.

**Improve wavefront sensor technologies.** The first step on the process is to improve precision on wavefront sensor technologies. Since single mode fibers (SMF) rely on adaptive optics corrections to have high coupling efficiency [1], it is crucial to have a wavefront sensor that will allow those corrections to be made. Keck is getting an upgrade on its wavefront sensor to a Pyramid Wavefront Sensor (PyWFS), which uses a predictive control technique called Empirical Orthogonal Functions (EOF) [[2](https://arxiv.org/abs/1909.05302)]. HISPEC is designed to optimize Keck’s adaptive optics system (AO) [1]; however, achieving full integration of the wavefront sensor and HISPEC will require extensive testing. **I plan on modelling the EOF's ability using a Python/SciPy script to improve wavefront error by introducing misaligments, defocus, and time delays.** These models will then be used to set tolerance limits on the opto-mechanical alignment. Using my experience at Lockheed Martin’s Santa Barbara Focalplane, where I work on the testing of infrared focal plane arrays, **I can lead on the performance of tests with the adaptive optics team at Keck to analyze and predict the wavefront error that will meet our instrument.**

**Implement wavefront control algorithms.** Although working on the adaptive optics system’s efficiency is a crucial step, analyzing how the instrument itself, HISPEC, responds to wavefront error is of equal importance. Algorithms that allow us to simulate how much a single mode fiber’s coupling efficiency changes as we introduce wavefront error allow us to calculate what is our current average coupling efficiency and identify what is the main optical aberration that is causing a decreased efficiency. By using my experience at JPL while working on Palomar Radial Velocity Instrument (PARVI), which inspired HISPEC’s design, I will provide HISPEC with a simulated result of its average coupling efficiency taking optical aberrations into account.During my JPL internship, I developed a Python routine to analyze PARVI’s coupling efficiency limitations as a function of wavefront errors. **I will work on adapting the previously written routine to generate commands to analyze HISPEC’s limits and help us better understand the instrument.** By accomplishing this goal, the HISPEC team will know what to work on to further improve the instrument and maximize its photon throughput, thus increasing its measurement precision.

**Work on HISPEC’s/MODHIS’ pipeline.** By using my experience writing for the Mazin Lab’s MKID Exoplanet Camera pipeline, I will write code for HISPEC’s pipeline that will extract the spectra of stars and acquire their radial velocities aiming for utmost precision. During the 5th year of this 7-year project, much of HISPEC’s limitations will have been understood and addressed, so the primary goal will be to have optimal data extraction. **I will develop efficient code for the HISPEC pipeline.** By deriving radial velocities for these stars using HISPEC’s pipeline, I hope to contribute to the detection of Earth-like exoplanets. Since the required precision for the detection of Earth-like planets using the radial velocity method is ~0.5 m/s [[3](http://www.eso.org/sci/publications/messenger/archive/no.114-dec03/messenger-no114-20-24.pdf)], HISPEC will be capable of detecting the shift in the star’s spectrum.

**Broader Impacts**

Overall, the field of exoplanet science is not only important to the scientific community but to everyone who looks at the sky and wonders what is out there, and whether we are alone in the universe. These research questions directly respond to NASA’s Exoplanet Research Program[[1]](#footnote-1) and can be answered if we develop the spectrograph and adaptive optics technologies for exoplanet detection. As a scientist, it is not my only job to contribute to this journey to better understand our universe. I will also work on the outreach of the scientific community. For that reason, I plan to create a Latinx in STEM group. The group will bring Latinx groups into science, ranging from middle schoolers to professors. It will allow Latinx scientists to discuss more about their current research projects and help inspire minority students into pursuing STEM careers. With weekly meetings at the University, current professors, scientists and graduate students can present more about scientific concepts and their journey with young students. The NSF GRFP would allow me to accomplish these goals during my graduate studies.

**References**

[1] Mawet, D., Fitzgerald M., Konopacky Q. et al 2019, arXiv e-prints, arXiv: 1908.03623

[2] Jensen-Clem, R., Bond C., Cetre D. et al 2019, arXiv e-prints, arXiv: 1909.05302

[3] Mayor M. et al 2002, The Messenger (ISSN0722-6691), n. 14, p. 20-24

1. http://exoplanets.nasa.gov/ [↑](#footnote-ref-1)