Caltech Astronomy Graduate Program Logan Pearce

Statement of Purpose

I intend to complete a Ph.D in astronomy research in the field of extrasolar planet and brown dwarf high-contrast imaging and formation. Following completion of my Ph.D, I intend to continue to work as an astronomy researcher, ideally at an observatory or research institution such as NASA. University faculty is also a position I will consider. I intend to pursue a career path that will allow me to continue to do astronomy research.

My path to astronomy is non-traditional and non-linear, but **it is precisely because of this winding path I now know for certain that a career as a researcher in exoplanetary astronomy is the ideal path for my future.** Every choice I have made as a student, every opportunity I have pursued, has been with this goal in mind.

Although I have always had an interest in astronomy, I obtained a bachelor's degree in chemistry from Purdue University as a traditional college student in 2003, and earned a commission as an **officer in the US Navy** upon completion. I sought appointment in the Navy's nuclear propulsion program because of the degree of academic challenge it afforded. I was not disappointed. The academic rigor in the schooling and subsequent work in the fleet is unparalleled by anything in the civilian world, in my experience. I served in many roles during my 5 years in the Navy, but the most impactful for me was as a nuclear power plant operator and maintenance division supervisor aboard the aircraft carrier USS John C. Stennis (CVN-74) for over 2 years in both war-time and maintenance conditions. In that capacity, I was continually challenged as a learner, a decision-maker under pressure, and a leader of personnel. The skills and experience I gained from that short intense time are too numerous to recount in detail here, but are an essential part of who I am and a factor in all my successes going forward.

Following separation from the Navy in 2008, I obtained a teaching certification and served as a **middle school science teacher** in Texas for 6 years. I taught in an advanced magnet program, and I focused my classes on teaching physics and engineering. I believe strongly in the power of engineering projects to drive student intellectual development, and so in 2014 I completed a Master's degree in engineering education in which I conducted original research on the effects of a well-designed engineering lesson on student development, while working as an in-service teacher. I also designed a popular elective course at my school in which students designed a crewed mission to Mars. The students' excitement in studying space rekindled my own long-forgotten love of astronomy, and I decided to leave teaching to pursue a career as an astronomer. It had been so long since I had studied math and physics that I quickly realized I needed to re-learn the basics to be successful as a researcher, and I am glad I did. I found the truth of the saying "I didn't know what I didn't know".

I began a **second bachelor's degree in astronomy and physics** at the University of Texas at Austin in 2015. Because I entered with the goal of becoming an astronomy researcher, I immediately set about the process of obtaining as many skills and diverse set of experiences as possible. I began with a job in the Hobby-Eberly Telescope Dark Energy Experiment instrumentation laboratory, assembling the units of the VIRUS instrument for UT's ambitious research project to measure the expansion rate of the universe. During my first summer I participated in a Research Experience for Undergraduates (REU) at Northern Arizona University (NAU) in the field of planetary science.

Working with Dr. Jennifer Hanley in NAU's Astrophysical Ices Laboratory, I carried out a laboratory experiment to measure the freezing points of various liquid mixtures which could compose the lakes on the moon Titan, to determine if it is possible for the lakes to freeze during Titan's seasonal variations. My work is featured in an article submitted to Nature Astronomy in November 2018. I spent this past summer with the Berkeley SETI Research Center at the University of California Berkeley, on the Breakthrough Listen (BL) project to search for technosignatures in primarily radio wavelengths. Working with Howard Isaacson, I developed the "1 Million Star" target list for BL's upcoming observing campaign with the MeerKAT telescope in South Africa, which will be the largest Search for Extraterrestrial Intelligence (SETI) search in history.

But the most impactful research experience was my work Dr. Adam Kraus on **an orbit study of the wide planetary mass companion GSC 6214-210 b.** Dr. Kraus' program has been monitoring several of these type of companions for many years with images from the Keck Telescope in Hawai'i, enough time to measure orbital motion. Planetary mass companions (PMCs) are large companions ($\sim$13 M_{jup}) on wide orbits ($\geq$100 AU) from their hosts that have been detected in imaging of young systems. I find PMCs exceedingly interesting because they occupy a parameter space that is difficult to explain with current brown dwarf and planetary formation mechanisms. They are too massive and too wide to be formed in situ through core or pebble accretion, but too small to have collapsed directly from the same molecular cloud as the host star without a mechanism for truncating the growth, which requires fortuitous timing. In my own work on the PMC system GSC 6214-210, I measured the astrometric relative motion of GSC 6214-210 b, fit Keplerian orbital parameters to the motion, and studied the fit for clues which could point to formation mechanism. To measure the astrometry, I built my own Markov Chain Monte Carlo (MCMC) Point Spread Function fitting algorithm, which astrometric achieved precision of $\approx$ 1 mas. To fit orbital parameters to the astrometry, I built my own rejection sampling fitting algorithm based on the methods of Orbits for the Impatient (Blunt et al., 2017). I concluded that the 14.5 M_{jup} companion was unlikely to have formed at a close radius, where the protoplanetary disk is thicker, and then been scattered out to its current wide orbit through a dynamical scattering interaction. This is in agreement with findings about some wide PMC systems (e.g. Bryan et al. (2016)) but not others (e.g. Ginski et al. (2014)). Thus there does not appear to be a clear trend among these objects suggesting a common formation pathway.

Study of these systems is hampered by the exceedingly small population that is known today. Bowler (2016) determined the occurrence rate of planets (5-13 M_{jup}) at separations observable in imagining (30-300 AU) to be only $0.6^{+0.7}_{-0.5}$%. But in addition to studying population statistics for these systems, direct imaging of giant planet companions is a valuable tool for study of extrasolar planets because of the ability to study the planet directly, rather than through its influence on the host star. These valuable systems are being used to inform planetary evolutionary models, distinguish between planet formation pathways, and determine the dependence of atmospheric clouds on mass and age. However, more giant planets are needed to develop meaningful statistical characterization of this population group and their host stars, and understand them as outcome of the planet formation process. With such a low occurrence rate, direct imagining survey strategies must be optimized to select targets that maximize the likelihood of finding a giant planet or brown dwarf companion.

This led me to propose a project for the NSF Graduate Research Fellowship Program to use multi-epoch astrometry to optimize a target list to detect new directly imaged companions. As recent studies have shown (Snellen & Brown (2018), Bowler et al. (2018), Calissendorff

& Janson (2018)), the large time baseline between *Hipparcos* and *Gaia* astrometry allows for detection of long period accelerations due to the presence of a companion of a wide orbit. Thus, by comparing the two epochs, I proposed to look for stars experiencing acceleration, and develop a target list optimized to identify companions based on the magnitude of the acceleration (to be consistent with planet masses), stellar multiplicity (to rule out binary systems), distance (closer objects will have larger angular separations), and age of host star (younger planets will be brighter). I then proposed to follow up the target list of $\sim$50 targets,which is the upper end of the number of targets that could reasonably be surveyed during my PhD tenure, with a high-contrast imaging survey to detect the companions.

Caltech is an ideal institution to carry out this study. Your institution comes highly recommended to me as a hub for exoplanet research, particularly in the subfield of high-contrast imaging. The access to observing resources at Caltech is unparalleled, and also makes it a ideal place for my research. My undergraduate work was conducted using NIRC2 data from Keck Telescope, and I even was able to travel to Keck with Dr. Kraus in 2017 to collect more data for my project, and fell in love with observing there and with Hawaii. I would ideally like to continue to pursue high contrast imaging with Keck.

However the main reason I would like to study at Caltech is the expertise of your exoplanet community. Several of the experts I referenced in my PMC work are from Caltech, including Dimitri Mawet, Heather Knutson, and Marta Bryan. My interests are in line with the work of Dr. Dimitri Mawet on high contrast imaging of giant planets and the vector vortex coronagraph. Additionally, he comes highly recommended to me as a researcher and a mentor. Heather Knutson's research program also is directly related to my research work to date, and is spoken highly of by colleagues at UT Austin. Additionally, I collaborated with Sarah Blunt, among others, on the "orbitize" project, an open source python orbit fitting package for the directly imaged planet community, while she was at Caltech. She recommends your program very highly. The exoplanet community at Caltech, from what I have learned about your program, sounds like just the kind of learning and research atmosphere I am looking for in a Ph.D program.

I am excited about the project I have proposed for NSF funding, and how well it would be served at Caltech, however **I am open to other exciting research ideas as well.** I am committed to pursuing exoplanet research, and I very much enjoyed the high contrast imaging work I have done previously, and would like to continue in it. But I know that plans have a high likelihood of changing, and I am very flexible and open to adjusting the course of my Ph.D work. I do hope to be able to pursue my Ph.D at Caltech for all of the reasons I have listed above, in addition to the appeal of living in California. Thank you for considering my application to your prestigious research institution.

References

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