Identifying Exo-Earth Candidates in Direct Imaging Data Through Bayesian Classification
A. Bixel\textsuperscript{1,3} and D. Apai\textsuperscript{1,2,3}, \textsuperscript{1}Steward Observatory, The University of Arizona, \textsuperscript{2}Lunar and Planetary Laboratory, The University of Arizona, \textsuperscript{3}Earths in Other Solar Systems Team, NASA Nexus for Exoplanet System Science

Introduction: Future space telescopes such as HabEx\textsuperscript{[1]} and LUVOIR\textsuperscript{[2]} could be able to directly image several Earth-sized planets in the habitable zones of nearby stars. Through deep follow-up spectroscopy, astronomers could then determine whether these planets are habitable and search for signs of life. However, these exo-Earth candidates (EECs) would be initially difficult to distinguish from the $\sim 10$ times as many planets with bulk compositions and surface temperatures not hospitable to life\textsuperscript{[3]}. An efficient survey of nearby planets must therefore rely on a scheme for identifying the most promising candidates for follow-up spectroscopy while rejecting the many potential “false positives”.

Methods: In our recent paper\textsuperscript{[4]}, we demonstrated a Monte Carlo method for interpreting direct imaging observations of an exoplanet within the context of existing observational and theoretical prior knowledge about exoplanet properties. This allowed us to place constraints on the planet’s size, mass, and orbit, and to calculate the probability that it is, in fact, an EEC. For an example of our method’s application to a hypothetical exoplanet, see Figure 1. Furthermore, this method can be adapted to incorporate new prior knowledge which may be attained within the coming decade.

Next, using realistic assessments of the targeted host stars and detected planet yield of LUVOIR\textsuperscript{[2]}, we conducted a mock survey in which we prioritized planets by the likelihood that they are habitable as inferred from a single epoch of direct imaging data, then submitted them for spectroscopic follow-up observations in order of priority. From this, we calculated the efficiency with which the true EECs were characterized - and potential false positives discarded - over the course of the mock survey.

Discussion: We have shown how our method of prioritizing targets for spectral followup with a single epoch of data is advantageous compared to blind target selection or a simple separation- and magnitude-based cut. We have also estimated the efficiency with which EECs can be identified given additional data - for example, by considering an independent detection through supporting radial velocity observations (e.g.,\textsuperscript{[5]}) or by using color information to discriminate between different planet types (e.g.,\textsuperscript{[6]}).

Finally, we will discuss the implications of our results for research and instrumentation development in the 2020s, and the survey strategy for space-based imaging missions once they are launched.

Future work: Our published results demonstrate the importance of leveraging prior research to enable future discoveries. Following this theme, we will discuss our ongoing effort to synthesize research in the areas of planet formation, planet statistics, habitability, and quantitative biology into simulations of planetary systems. These simulated systems will contain a diversity of plausible non-habitable, habitable, and inhabited environments, and can be used to formulate testable hypotheses and predict the output of next-generation ground- and space-based surveys.

References:
\textsuperscript{[1]} The HabEx Study Team. 2019, The HabEx Final Report, https://www.jpl.nasa.gov/habex/
\textsuperscript{[5]} Dressing, C., Stark, C. C., Plavchan, P., & Lopez, E. 2019, BAAS, 51, 268
How confidently can we identify exo-Earth candidates?

Figure 1: We simulate the detection and characterization of an Earth-sized planet in the middle of the LWHZ of a Solar-mass star at 15 parsecs distance. The planet is in fact an EEC, but the observer can only determine this with 31% confidence. (Left) We compare the planet’s observed separation and magnitude to those of several planets drawn from statistical prior distributions, and find that the majority of planets which appear similar to the target are not habitable. (Center/right) Posterior distributions for the planet’s semi-major axis and size; the true values are marked with dashed lines. Adapted from [4].