DISCOVERING HUNDREDS OF NEW EXOPLANETS WITH K2

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EXECUTIVE SUMMARY

The Kepler mission proved that space telescopes can discover thousands of exoplanets, including ones small and cool like the Earth. As the number and diversity of known exoplanets grow, we learn more about how our own planet formed and evolved, as well as how common other Earthlike planets may be in our universe. Both the K2 and upcoming TESS missions provide millions more star systems to search for planets, but there are not any mission-funded efforts to do so.

We developed a flexible, comprehensive planet search pipeline to discover exoplanets around the K2 and TESS targets. It has discovered hundreds of new planet candidates in K2 and TESS promises to deliver even more. These new planets orbit stars vastly different from the ones the Kepler mission studied. Combining the exoplanets from this research with the known ones from Kepler, we can learn how planets form and how common they are around stars of all types.

RESEARCH CHALLENGE

Kepler's haul of over two thousand confirmed planets, most smaller than Neptune, changed the field of exoplanet research. We learned that small planets are ubiquitous and that planets similar to the Earth may be common in our galaxy [1]. Recently, evidence has emerged that reveals a gap in small-planet radii: Planets are either smaller than about 1.5 times the size of the Earth or more than twice as large, with relatively few planets of intermediate sizes [2]. This radius gap hints that planets with rocky cores may form up to about 1.5 times the size of the Earth, but some have an added puffy hydrogen and helium atmosphere inflating their radii to more than twice the Earth's. However, all of this work has been done with planets around stars like our sun; we still know little about planets around other types of stars, including our galaxy's smallest and most numerous red dwarfs.

The Kepler mission has been succeeded by K2, which studies more diverse stars. Yet because of the telescope's reduced data quality in its extended mission, searching for planets is not as easy, and there is no official effort to do so. The goal of this project is to develop a pipeline that accounts for the increased noise of K2 data and to search for planets. By finding planets around smaller stars, we will learn if the radius gap observed around larger stars holds true and get a better handle on what causes it in the first place. We can also constrain the occurrence rate of small planets around these smaller stars to see how common Earth-sized planets are in the much closer "habitable zones" surrounding the smaller stars.

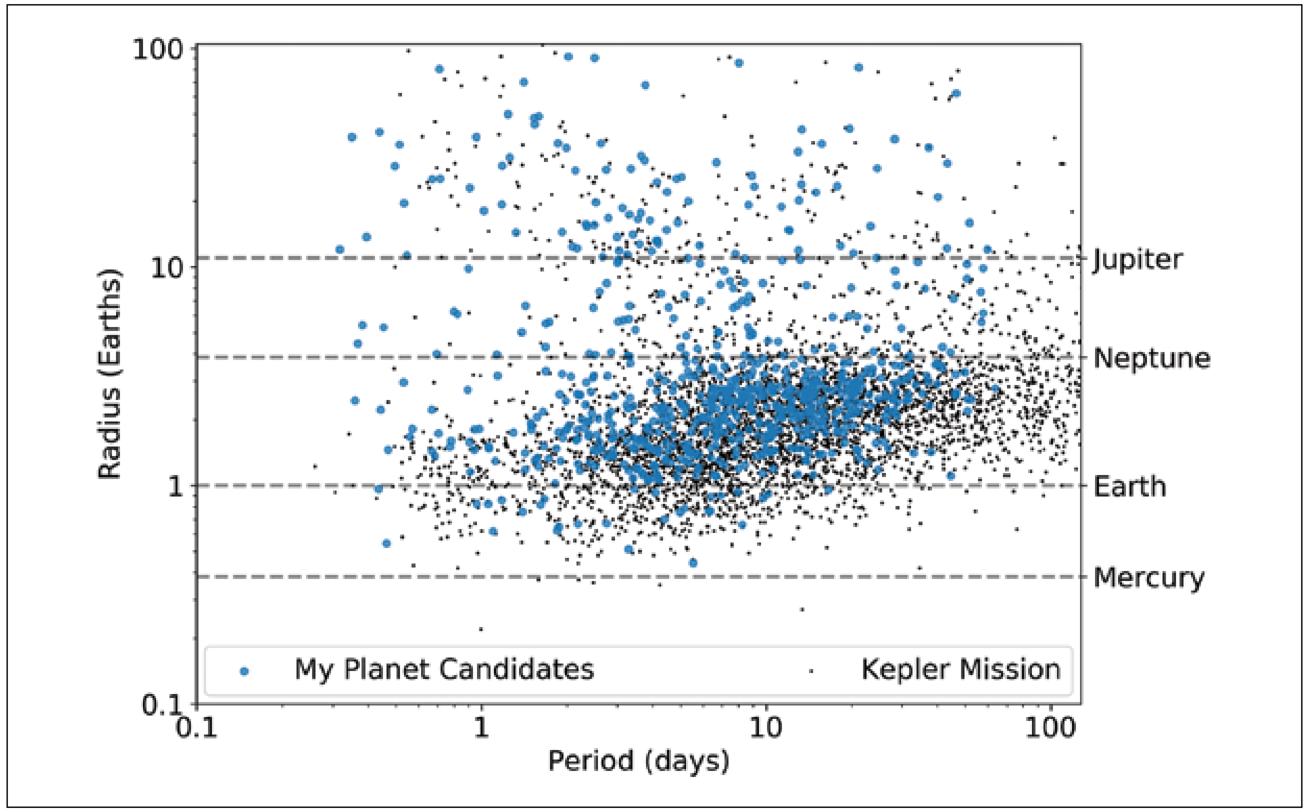

Figure 1: Our K2 exoplanet candidates with those from the original Kepler mission, showing we are finding a similar population of planets. A K2 campaign is limited to 80 days of observation compared to Kepler's four years, preventing us from finding the longer periods and smaller planets.

METHODS & CODES

The raw K2 data is very noisy due to the telescope's loss of fine pointing. First, we developed a technique that separates the instrumental noise from the astrophysical noise, in a process called pixel-level decorrelation. We run this processing pipeline (called EVEREST) on every star to create light curves with noise at about a factor of four better than the raw light curves: a precision that allows for planets to be found again [3].

These EVEREST light curves are then brought over to Blue Waters to search for planets. I have developed a general-purpose transit search pipeline based on an algorithm called QATS [4]. My transit pipeline can find not just the usual periodic planets but also planets that are overlooked in other planetary searches. Namely, those that transit only once or twice as well as those with transit timing variations due to perturbations by other planets in the system. Altogether, we have developed the most sensitive and comprehensive planet search pipeline for K2 data.

RESULTS & IMPACT

We searched the first two years of K2 data for new exoplanet candidates and discovered over 700. As with the original Kepler mission, most of these planets are smaller than Neptune, but unlike Kepler the majority orbit stars smaller than the sun and are closer, brighter, and easier to study in depth. Furthermore, because the K2 stars are scattered across the sky in different environments, we can learn about planet populations throughout the galaxy.

Identifying these candidates is just the first step. Adding a large, diverse pool of planet candidates to our sample will enable a suite of follow-up studies. Detailed observations of individual candidates will teach us about planet compositions and atmospheres. Comparing statistical samples of planets in different environments will help test planet formation and evolution theories.

WHY BLUE WATERS

Searching for planets is an enormously computationally intensive task. Going in, we don't know a potential planet's period, transit depth and duration, or ephemeris. Thus, searches are effectively over a four-dimensional grid of all possible parameters, and searching for a single star takes around an hour. With over 200,000 stars to search in the first two years of K2 data alone, large computing power is necessary. Access to Blue Waters speeds up development and processing, ensuring that our planet candidates get out in a timely manner for quick follow-up by the community.

As a sixth-year PhD student in astronomy at the University of Washington, Kruse works under the supervision of Eric Agol.