Kepler Exoplanet Analysis

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***Abstract*— mother Earth is inhabited by 7.8 billion people as of March 2020. These staggering numbers cannot be overlooked. We have about 50 years' worth of resources after which we will be faced with serious problems. This alarming situation we are in calls for exoplanet research. It seems ridiculous to suggest that Earth might be the only planet in the whole universe capable of supporting life. The search for extrasolar planets has become a subject of intense scientific investigation over the years with a hope to find habitable planets in other galaxies. Determined to solve this problem, we have chosen to solve it based on data available from NASA's Kepler Mission.**

Keywords- exoplanets, kepler mission, habitability

I. Introduction

One of the most profound and thought-provoking questions that humanity has ever asked is, "Are we alone in the universe?" Philosophers have asked this question for thousands of years, but we are the first generation with tools at our fingertips to be able to answer this question with scientific observations.

With the rate at which our population is our population is likely to become too large to be supported by Earth. One might argue that these things won't happen for a long time so we don't need to worry about it right now. Counter to that, one can argue that we don't know how long it will take to overcome the formidable challenges and make the necessary scientific discoveries and that it may not happen if we don't work on these things now.

Exoplanet research is not as simple as pointing a telescope upward and looking for a planet that waves back. Scientists must gather many observations and carefully analyze their data before they can be even somewhat sure that they've discovered new worlds.

ground. But telescopes don't capture photos of planets with nametags. Instead, telescopes designed for the transit method show us how brightly thousands of stars are shining over time.

To find a planet, scientists need to get data from telescopes, whether those telescopes are in space or on the ground.

If the star's light lessens by the same amount on a regular basis, for example every 10 days, this may indicate a planet with an orbital period of 10 days. The standard requirement for planet candidates is at least two transits, i.e. two equal dips in brightness from the same star.

Not all dips in a star's brightness are caused by transiting planets. There may be another object such as a companion star, a group of asteroids, a cloud of dust or a failed star called a brown dwarf, that makes a regular trip around the target star. There could also be something funky going on with the telescope's behavior, how it delivered the data, or other 'artifacts' in data that just aren't planets. Scientists must rule out all non-planet options to the best of their ability before moving forward.

With such a complicated procedure involved in exoplanet research and resources depleting at an exponential rate, it becomes important to use the computational power that we have today to analyze the data that is available and make sense of it in an effort to expedite the speed of research.

One such mission that aimed at exoplanet research is the Kepler mission run by NASA. It has sent back the biggest bounty of confirmed exoplanets of any telescope, more than 2,600 to date. The data that was collected as part of this mission was made available for the public.

Scientists have uncovered the presence of exoplanets with the help of people like us. For instance, exoplanet K2-138 was discovered through citizen scientists in Kepler’s K2 mission data.

Based on surveys so far, scientists calculate that almost every star in the Milky Way should have at least one planet. That makes billions more, waiting to be found. Motivated by the it, we have decided to pick it up as the topic of our project.

II. LITERATURE SURVEY

Ji-Wei Xie et al. in their paper ‘Exoplanet orbital eccentricities derived from LAMOST-Kepler analysis’ make an interesting set of observations that Kepler multiples and solar system objects follow a common relation between mean eccentricities and mutual inclinations.

They have done so by deriving the eccentricity distributions of an unprecedented large and homogeneous sample of 698 Kepler planets using the precise spectroscopic host star parameters from the Large Sky Area Multi-Object Fiber Spectroscopic Telescope observations. A dichotomy in eccentricities has been discovered.

Kepler singles are on eccentric orbits whereas the multiples are on nearly circular and coplanar orbits similar to those of the solar system planets. The systems with single transiting planets, which make up half of the sample have a large mean eccentricity, whereas the multiples are on nearly circular orbits. The average eccentricity and inclination of the Kepler multiples and the solar system objects fit into an intriguing common pattern.

One important concern about the eccentricity dichotomy is the likely larger false positive (FP) rate of the singles compared with that of the multiples.

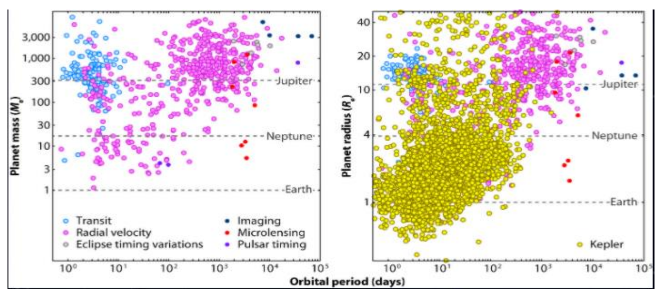
Considering the pros and cons, this paper successfully implies that the solar system is not so atypical in the galaxy and opens a wide door for the discovery of possible habitable planets.

Ms. Sara Seager is a professor at MIT. Her research focuses on detecting an earth like planet among the exoplanets that we know today. The diagram below shows that exoplanets have all masses and semi-major axes possible, showcasing the random nature of planet formation and migration. The different planet detection techniques are shown in the diagram. Parts of the diagram with no planets are where technology cannot yet reach exoplanets. The figure below shows exoplanet discovery space as of 2014.

Plotted as mass vs. orbital period (left) and not including Kepler discoveries.

Plotted as radius vs. orbital period (right, and using a simplified mass-radius relationship to transform planet mass to radius) shows just how many exoplanets have been discovered, most by the Kepler Space Telescope.

The paucity of planets of Earth's size or mass and orbit emphasizes the challenge exoEarth discovery with any planet-discovery technique.



The habitable zone is a region around a star where a planet can have surface temperatures consistent with the presence of liquid water. All life on Earth requires liquid water, so the planetary surface temperature requirement appears to be a natural one. The climates of planets with thin atmospheres are dominated by external energy input from the host star, so that a habitable is based on distance from the host star. Small stars have a habitable zone much closer to them as compared to Sun-like stars, owing to their lower luminosity.

The surface temperature on an exoplanet is governed by the greenhouse gases or lack thereof. Specifically, the greenhouse gases absorb and reradiate energy from the host star, in the form of upwelling infrared (IR) radiation from the s surface. Whereas on Earth we are concerned with, e.g. parts-per-million rise in the greenhouse gas CO_2 concentrations, for potentially habitable exoplanets we do not know a priori and cannot yet measure what gases are in the atmosphere even to the tens of percent level. The atmospheric mass and composition of any specific small exoplanet is not predictable.