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Statistical Evaluation of Simulated Period Distributions of Exoplanets Using Julia

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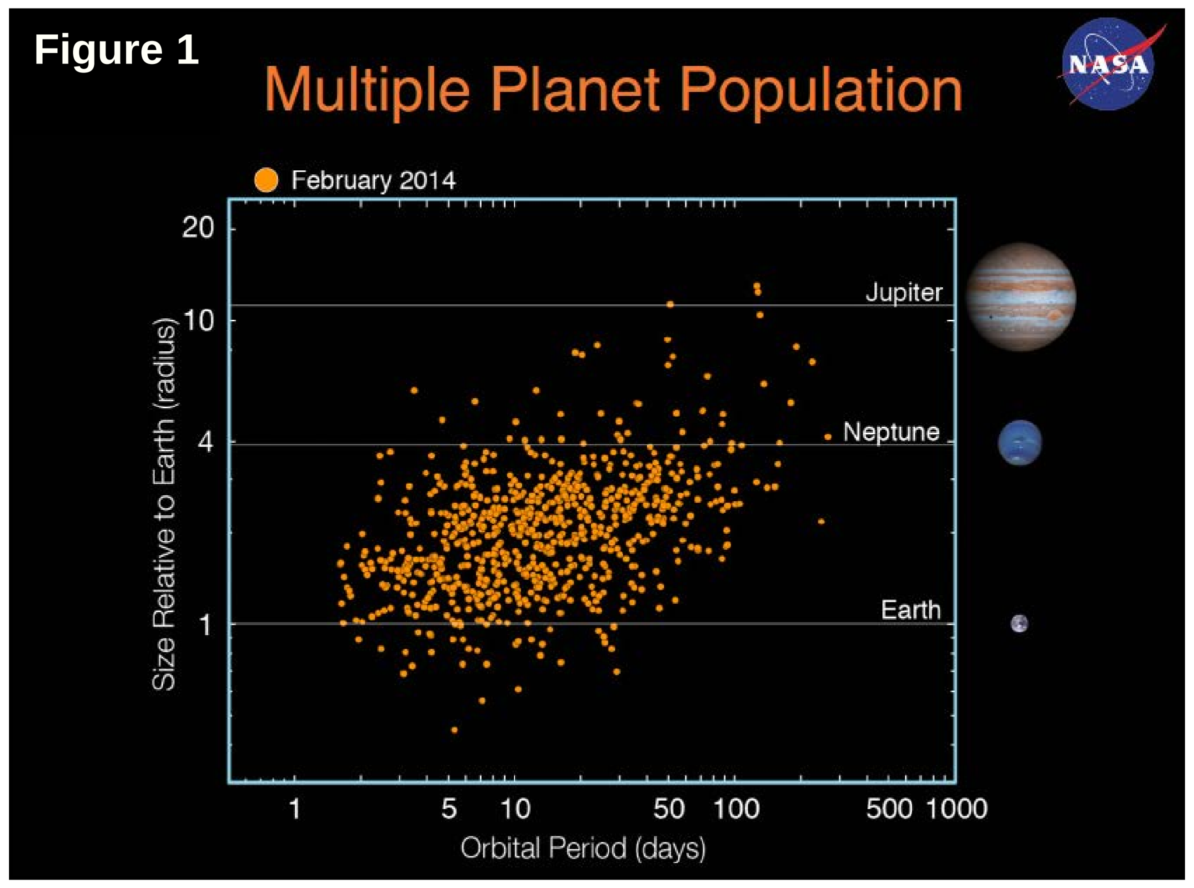
Scientific Background Summary

NASA launched the Kepler Space Telescope in March 2009 to observe the Cygnus-Lyra star field and search for Earth-like planets orbiting other stars in a habitable zone. Kepler has discovered and gathered data about thousands of **exoplanets–planets revolving around other stars**. Researchers study and analyze this data in order to distinguish exoplanets according to their individual characteristics; for instance, mass, radius, density, temperature, semi-major axis, and orbital period. An example of recent Kepler discoveries is shown in **Figure 1**, which illustrates the orbital period and planet size for systems with multiple transiting planets.



Introduction

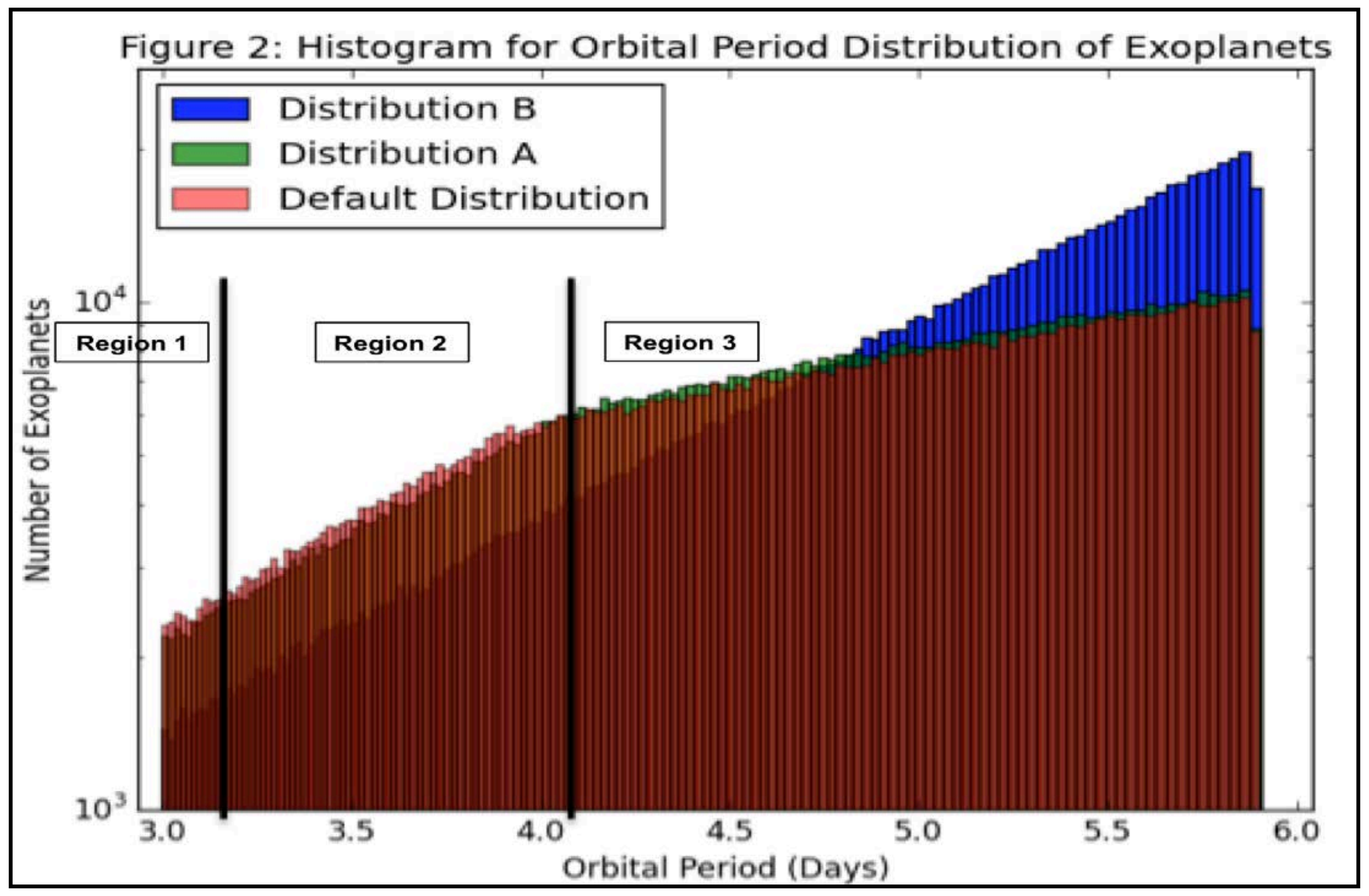
SysSim is the Planetary System Simulator that is developed by Dr. Darin Ragozzine in order to de-bias the Kepler Exoplanet Catalog. The main purpose of this research is to compile **a computer program** to analyze the differences using the **Approximate Two Sample Kolmogorov-Smirnov Test (K-S Test).** This was used to quantify the probabilities in order distinguish different orbital period distributions. In addition to this, **profiling** was used to test the speed of the computer program.

Research Techniques

Julia, **a new high-level programming language**, was used to apply the **K-S Test** in order to distinguish the given orbital period distributions (Distribution A and Distribution B) from the Default Distribution of 1000 exoplanets. Many distributions were examined; here we illustrate the method using Distribution A and Distribution B of exoplanets (**Figure 2**).

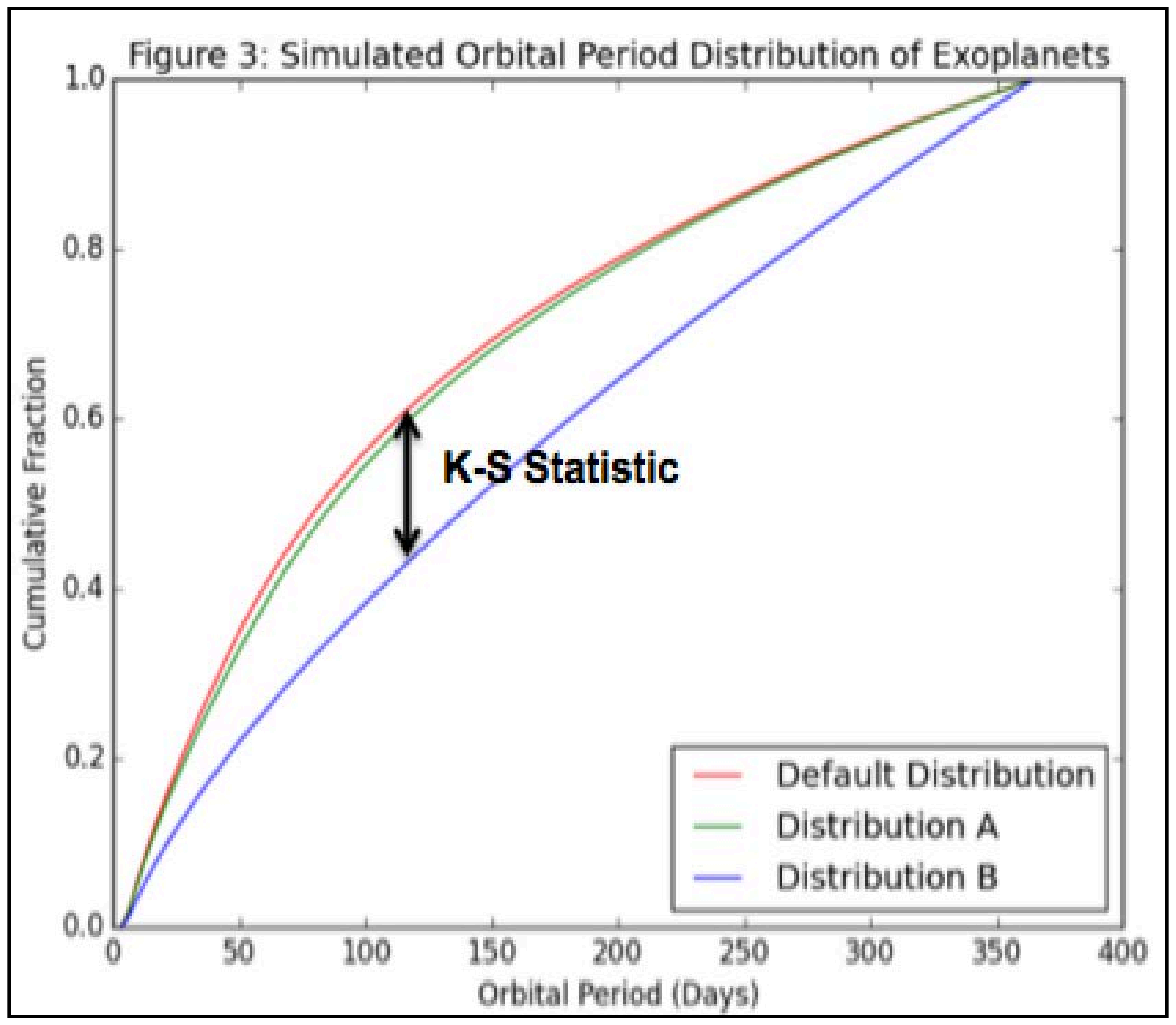
Results of the Approximate Two Sample Test

A histogram of 100,000 exoplanets for the Default Distribution, Distribution A, and Distribution B (**Figure 2**) was plotted to illustrate the orbital periods. The K-S Test was used to find the probability of difference between the Default and the sets of the orbital period distributions (Distribution A and Distribution B) of the first 1000 exoplanets. A probability of 100% signifies that a given orbital period distribution is indistinguishable. **The resulted probabilities for Distribution A and Distribution B were 40% and 6.12E-15% respectively.** This suggested that it was easier to distinguish Distribution B from the Default Distribution.



Power Laws of Simulated Orbital Period Distributions

A **power law** describes a functional relationship between two quantities and has a form **$f(x)=Cx^a$**, where a is the power law exponent. The observed period distribution is modeled by the Default Distribution. This requires three different power law exponents in three regions (**Figure 2**). For Distribution A, the power law exponents were equal to those of the Default Distribution; however, the division between Region 2 and Region 3 was 60 days instead of 50 days. Therefore, it was difficult to distinguish exoplanets from the exoplanets of the Default Distribution. For Distribution B, the triple power law exponent in Region 3 (50 to 365 days) was different than that of the Default Distribution by 0.58. Hence, it was easier to detect and distinguish 1000 exoplanets of Distribution B from the Default Distribution.



Using Julia, the average time required to run the K-S Test of the for orbital periods of 100,000 exoplanets was 1.2 *milliseconds.*
This was 10 times faster than the compilation time of the program using IDL.

Conclusion and Future Works

The results of K-S Test helped to quantify the probability to distinguish the given period distributions of exoplanets from the Default Distribution. **For Distribution B, the power law exponent in Region 3 was different than that of the Default Distribution by 0.58. Using the K-S Test, 1000 exoplanets from Distribution B were detectable and distinguishable from the Default Distribution.** The next step in this research would be to compare the results of the K-S Test using different statistical methods; for instance, Anderson-Darling (A-D), Baumgartner-Weiß-Schindler, and Cramér–von Mises Statistics. We will also compile the Default Distribution with the real distributions of exoplanets.

Acknowledgments

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NORTHROP GRUMMAN

Engineering & Science Student Design Showcase at Florida Institute of Technology