RAD-ASS: the RADius-mASS relationship of exoplanets

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Abstract

Using data from the NASA exoplanet archive[1], our group created a model of the relationship of exoplanet mass and radius. Noticing that there were two distinct groupings of exoplanets[2], we performed a linear least squares regression on each section. From these results, we attempt to explain the relationship between the planetary radius and planet composition. Our data includes exoplanets observed using the transit method, as well as data from stellar radial velocity observation techniques.

Transits

Using the measurements of a star's light, astronomers can detect periodic dips in brightness to locate orbiting exoplanets. The transit method provides information about the radius, orbital period and orbital tilt of an exoplanet.

Radial Velocity

By taking spectral analysis of stars, astronomers can detect shifts in light wave frequency based on changes in velocity due to the gravitational pull of exoplanets in the star's system. Astronomers then use this data to calculate the relative exoplanet mass.

Data

- By plotting mass and radius data from the exoplanet archive[1], our group found two distinct correlations between planetary mass and radius.
- Our group fit the data with a continuous piecewise function of two lines using a nonlinear regression.
- The exponent of "m" is determined by planetary composition.
- For large planets about the mass of Jupiter, the addition of more mass does not increase the radius as much as for smaller planets, explaining the change of slope at 200 earth masses.[3][4]
- The experimental data was in terms of earth radii and mass. Other solar system planets were also added for scale.

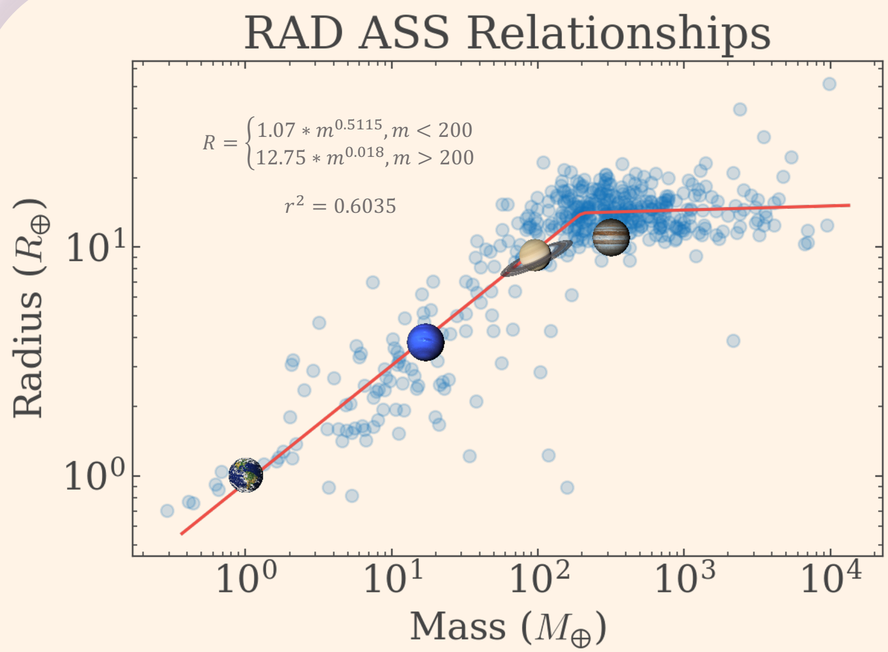

Figure 1: Plot of data and model. The data is shown as blue points and the model is the red line. A few solar system planets are shown for scale. Notice the clustering of exoplanets around Jupiter.

Conclusion

The apparent bias in the graph data is due to the relatively large number of more massive (larger than 100 earth masses) planets that were observed in our data set. Transits are most easily spotted when a planet has a larger radius close to its host star, and the Radial Velocity method is most sensitive to more massive planets also in a close orbit to their host star. Despite these limitations, we were able to graph both distinct correlations. Because our model uses a linear regression, the best fit line can be too sensitive to outliers. Our model also does not account for errors in data or the possibility or a more complex, nonlinear trend.

Additional studies might investigate how the density of different materials and their distribution in the planet play a role in the mass and radius relationship, which may be observed through calculation the volumes of planets. In the future, more complex models could be used that also account for the error of each data point.

References

[1] "This research has made use of the NASA Exoplanet Archive, which is operated by the California Institute of Technology, under contract with the National Aeronautics and Space Administration under the Exoplanet Exploration Program."

[2] Angus, R. (2015, May 02). Exoplanet masses, probably. Retrieved August 21, 2020, from https://astrobites.org/2015/05/02/exoplanet-masses-probably/

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[4] Swift, Damian & Eggert, J. & Hicks, Damien & Hamel, S. & Caspersen, K. & Schwegler, E. & Collins, G. & Nettelmann, Nadine & Ackland, Gj. (2011). Mass-Radius Relationships for Exoplanets. The Astrophysical Journal. 744. 59. 10.1088/0004-637X/744/1/59.