Approximating Atmospheric Retention in Exoplanets

Background/Introduction/Methods

Atmospheric retention in an exoplanet describes whether the exoplanet is capable of maintaining an atmosphere. This phenomenon occurs due to a variety of factors such as stellar wind from stars, whether it has a magnetic field, tidal forces, etc.

One sure way of determining whether an exoplanet has atmospheric retention is by measuring whether the thermal velocity of the atmosphere is less than the escape velocity of the exoplanet.

Thermal velocity is given by the equation, where T is the atmospheric temperature, and m is the average mass of a gas particle:

$$v_{\text{thermal}} = \sqrt{\frac{3k_B T}{m}}$$

Escape velocity is given by the equation, where M & R are mass and radius of the exoplanet, respectively:

$$v_{\text{escape}} = \sqrt{\frac{2GM}{R}}$$

However, knowing the average mass of a gas particle of exoplanets or the atmospheric temperature is difficult for a wide range of exoplanets. Because of this, an approximation was made and surface temperature was used instead of atmospheric temperature. It is important to note that surface temperature is typically greater than atmospheric temperature.

The equation for surface temperature is given by the equation, where Teq is the equilibrium temperature of the exoplanet:

$$T_{\text{surface}} = T_{\text{eq}} \sqrt[4]{1+f}$$

For the purposes of this project , the constant value of the fourth root of one plus f will be represented by “Gf” which I defined as the “Greenhouse Factor”.

To study atmospheric retention I used data from the NASA Exoplanet Archive to collect and plot data representing escape velocity, thermal velocity, and distance from earth of each respective exoplanet. The data collected contains information about equilibrium temperature, orbital parameters, exoplanet mass, and information about their stars. [The Data can be found at https://exoplanetarchive.ipac.caltech.edu/]

Results/Discussion

I created a function that plots four different subplots relating thermal velocity and escape velocity to distance, taking in parameters that represent the “Gf” greenhouse factor and “mu” the average mass of a gas particle. Figure 1 represents the conditions for an Earth-like exoplanet, and Figure 2 represents the conditions for a planet with a very large greenhouse factor and a smaller average mass of the gas particles in the atmosphere (ideal conditions exploring the lack of atmospheric retention).

Figure 1

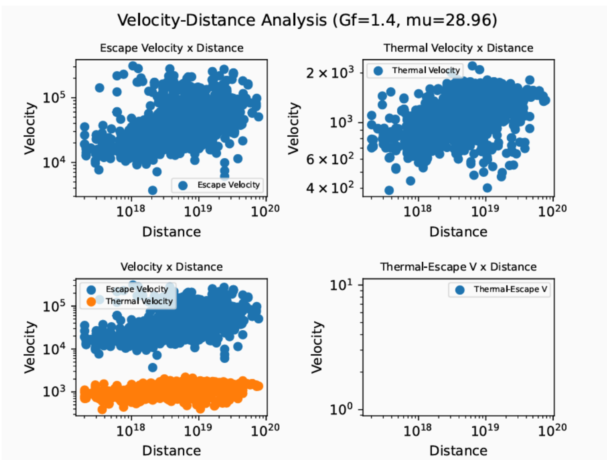
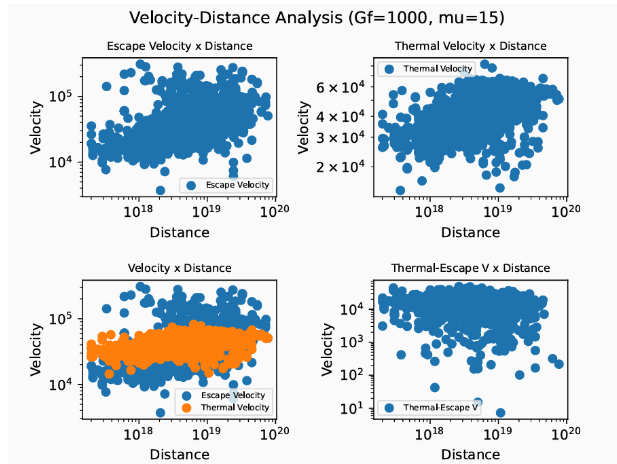


Figure 2



As evident from the “Thermal-Escape V x Distance” Graph on Figure 1, there are no exoplanets where the thermal escape velocity is greater than the escape velocity. This is expected, because earth-like planets should have atmospheric retention. The lack of planets in this graph shows that no planets if they are earth-like have atmospheric velocities that are greater than their escape velocities.

A major finding by looking at the bottom graphs of figure 2 show that exoplanets that are closer to earth are more likely to not have atmospheric retention, while exoplanets that are further from earth have more chances of having atmospheric retention. This is shown as more planets have greater escape velocities further away from earth than planets closer to earths, while the average thermal velocities remain relatively constant across all distances. The existence of blue dots on the bottom right graph shows the planets which lack atmospheric retention (aka, all the instances where the orange dots are above the blue dots in the bottom left graph). These results can help future researchers know where to look when finding potentially habitable planets.