Exploring Exoplanet Detection Techniques

By: Daniel Zurawski, Victor Karkour, and Jake Kamen

Motivation

- Explore detection methods
  - Transits
  - Radial Velocity
  - Direct Imaging
  - Astrometry
  - Microlensing

- Determine pros and cons of these methods (When should we use each?)

Methods

- Planetary data set from the NEA website (contains masses, radii, semi-major axis, periods, etc.)
- Coding
- Equations and tables
- Plotting!! (using colab)

Transit:

$$R_p = R_E \sqrt{3\sqrt{\frac{P}{T}}}$$

RV:

$$m_p = K \cdot m_* \cdot \sqrt{\frac{a}{Gm_*}}$$

Imaging:

$$R_p = R_\star \sqrt{\frac{f}{\frac{e^{h\nu/k_B T_p}-1}{e^{h\nu/k_B T_\star}-1}}}$$

Methods part 2

- Transit method: Measuring the drop in light as planet passes in front of star.
- Using Radial Velocity: works by measuring doppler shift of spectral lines as star moves (shared center of mass)
- RV sensitivity is based on planet mass and the semi major axis
- Direct imaging sensitivity (instrument based)
- Limited by diffraction limit of telescope

Diffraction Limit

$$\theta = 1.22\frac{\lambda}{D},$$

Small Angle Approximation

$$\theta = \frac{a}{d}$$

Coding

- Some of the code!
- Used code to plot via colab
- Used this to create the plots coming up shortly

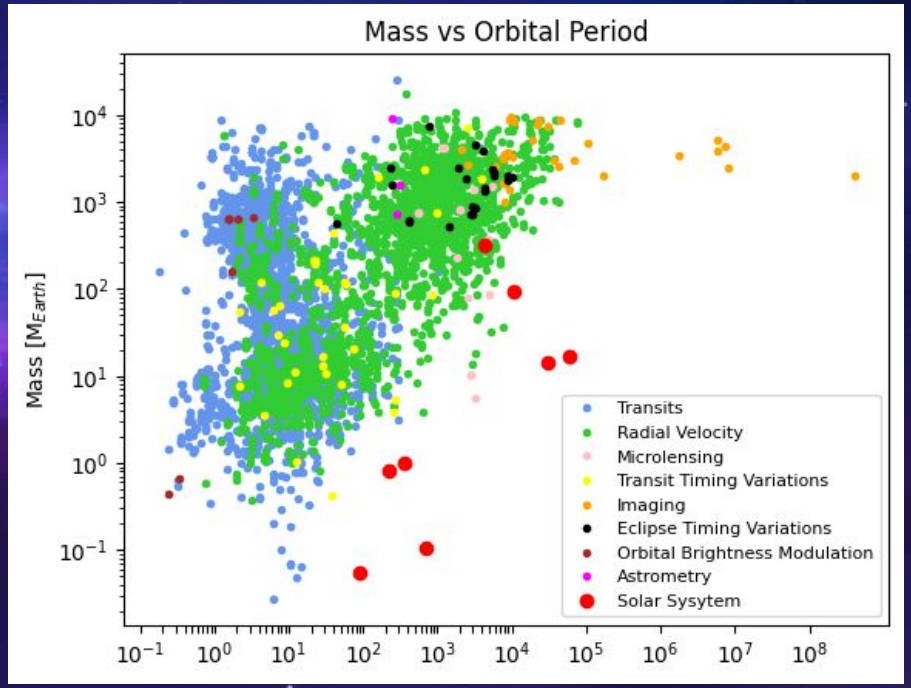
```
# Constants & Assumptions
h = ac.h # Units of Joule Seconds
c = ac.c # Units of Meters per Second
k = ac.k_B # Units of Joule per Kelvin
T_s = 5000 * u.K # Units of Kelvin of Star
T_p = 1000 * u.K # Units of Kelvin for Planet
l = 1.65 * u.micrometer # Units of microns
f = 1E-7 # Flux | Unitless
R_s = u.solRad

# Wavelength to Frequency
v = c / l

# Black Body Equation
B = (np.exp(h*v / (k*T_s)) - 1) / (np.exp(h*v / (k*T_p)) - 1)

# Total Equation
R_p = R_s*np.sqrt(f/B)
R_p = R_p.to(u.jupiterRad)
print(R_p)
```

```
0.11082832497786883 jupiterRad
```

Results

- Four key relationships
- Mass vs Period
- Mass vs Semi-major axis
- Radius vs Period
- Radius vs Semi-major axis

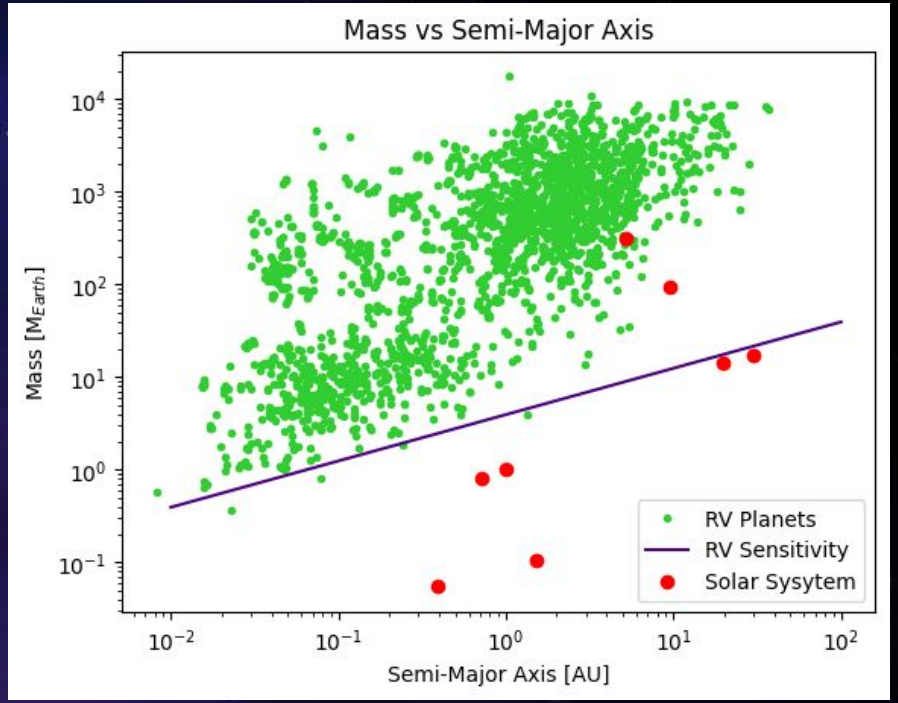
Mass vs Period Plot



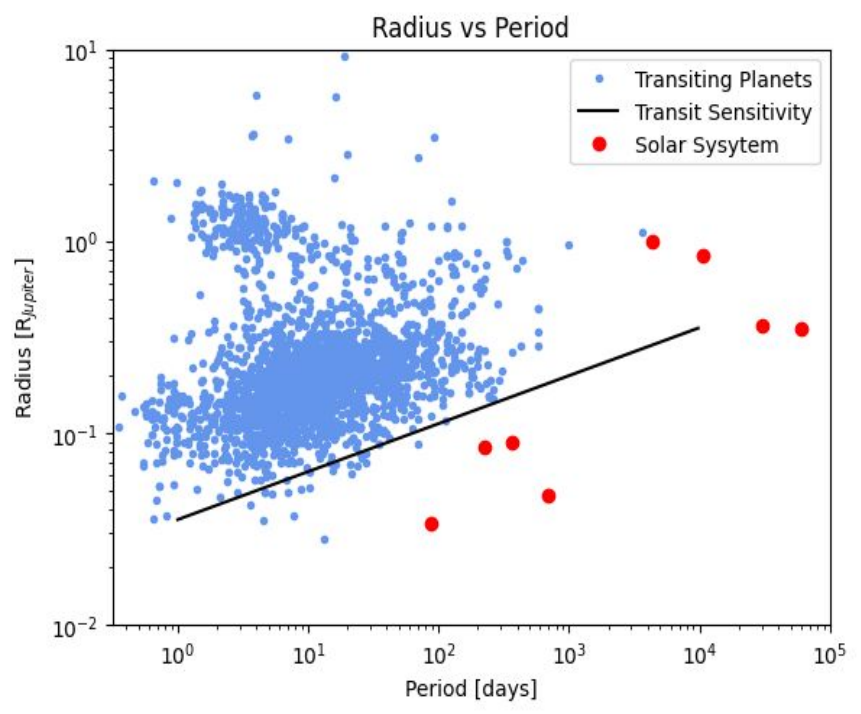
- Notice red dots for solar system planets
- Migration: Some planets beyond snow line can move slowly in towards the host star
- Explains the gaps

Mass vs Semi-Major Axis Plot

- RV sensitivity line
- Shows limits of Radial Velocity Detection
- Most of our solar system planets sit below the line!



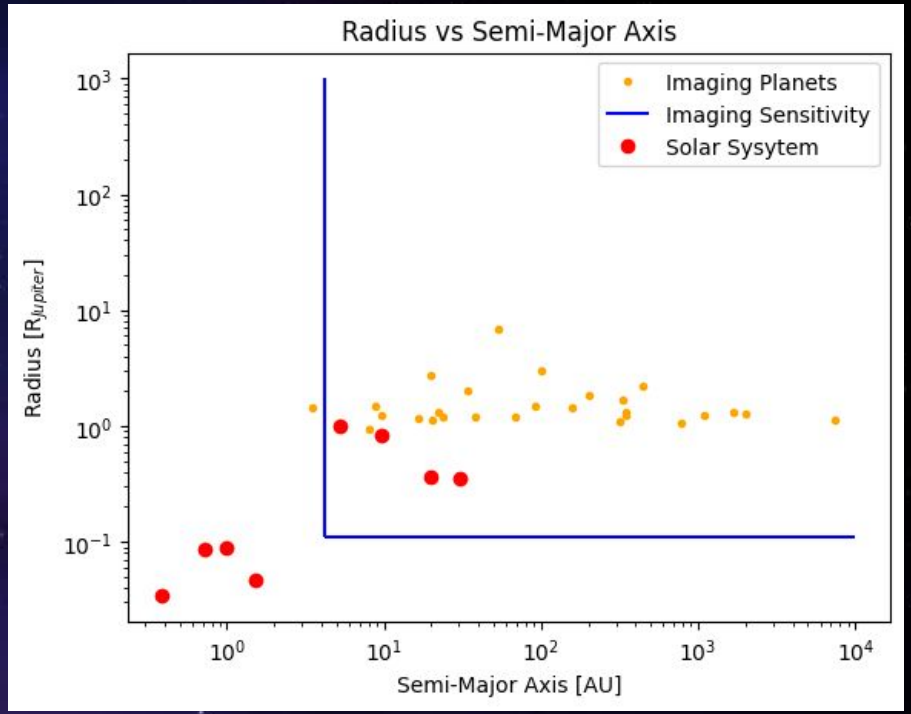
Radius vs Period Plot



- Transit sensitivity line
- Planets with larger radii have an easy time forming farther away from their parent star

Radius vs Semi-Major Axis Plot

- Imaging sensitivity line
- Shows sensitivity of Direct imaging method
- Minimum orbital separation (vertical line)
- Size of objects observing (horizontal line)
- Much larger limits than the others.



Conclusi

- Motivati
- Opinion