Measuring Planet Mass, Radius, and Density

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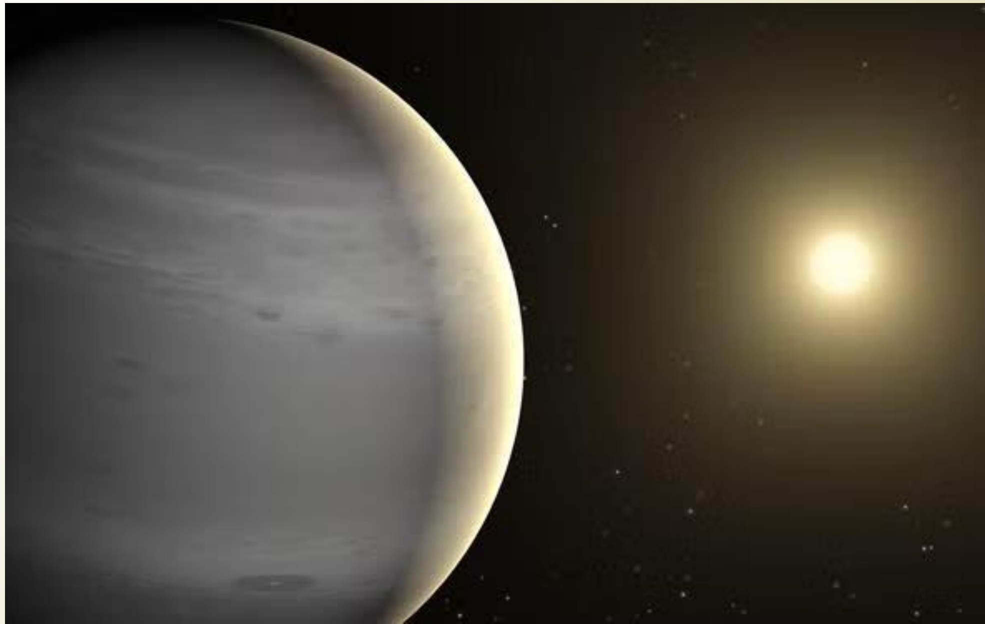
Introduction

Objectives/Goals:

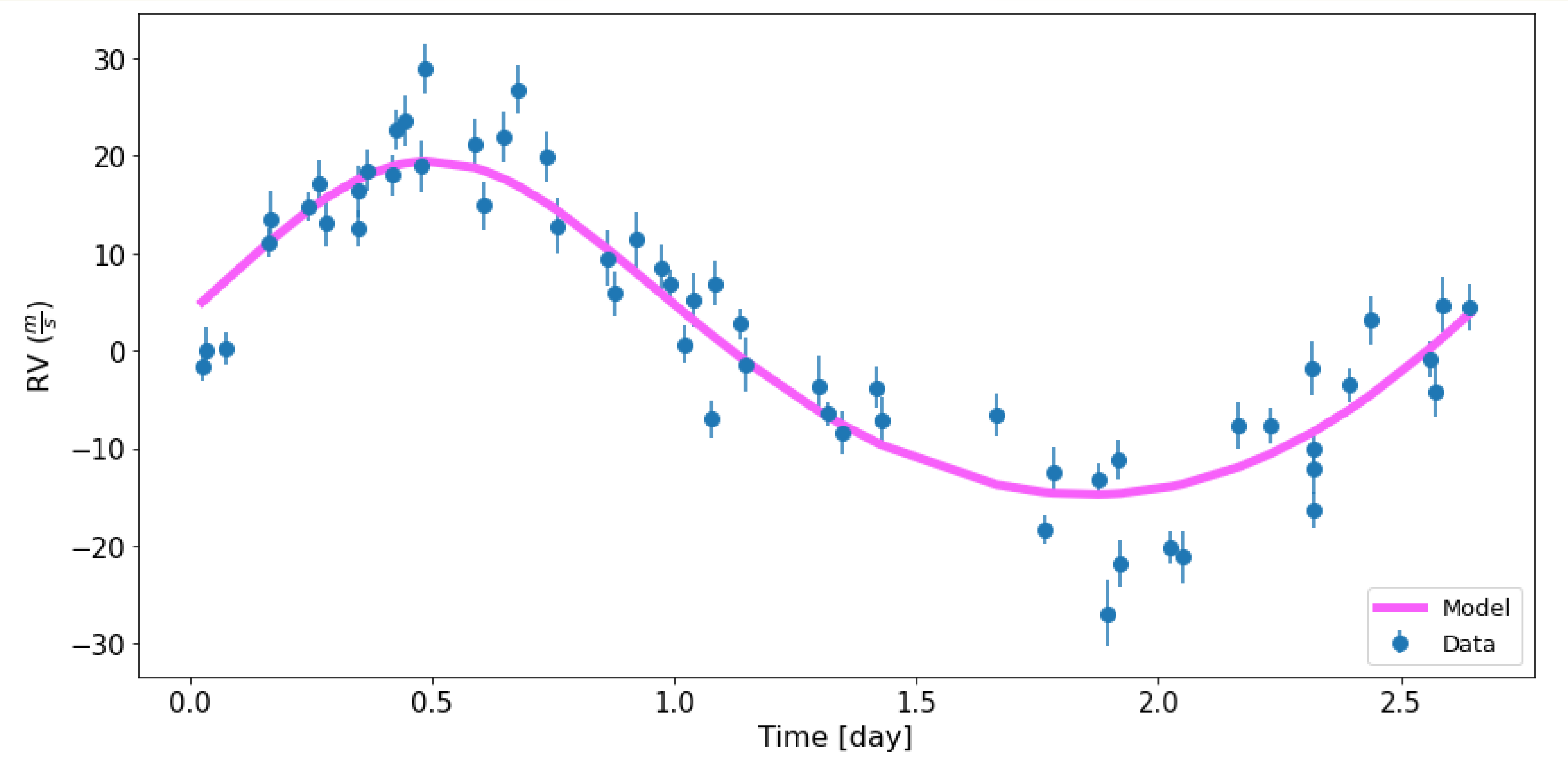
- Obtain data of a chosen exoplanet
  - Radial Velocity & Transit Data
- Find the mass based on radial velocity data
- Find the radius based on transit data
- Use the mass/radius to calculate density

- **Chosen Planet: GJ 436 b**



Methods

- Use NEA to obtain transit & RV data
- Use Python to plot the data and calculate mass, radius, & density



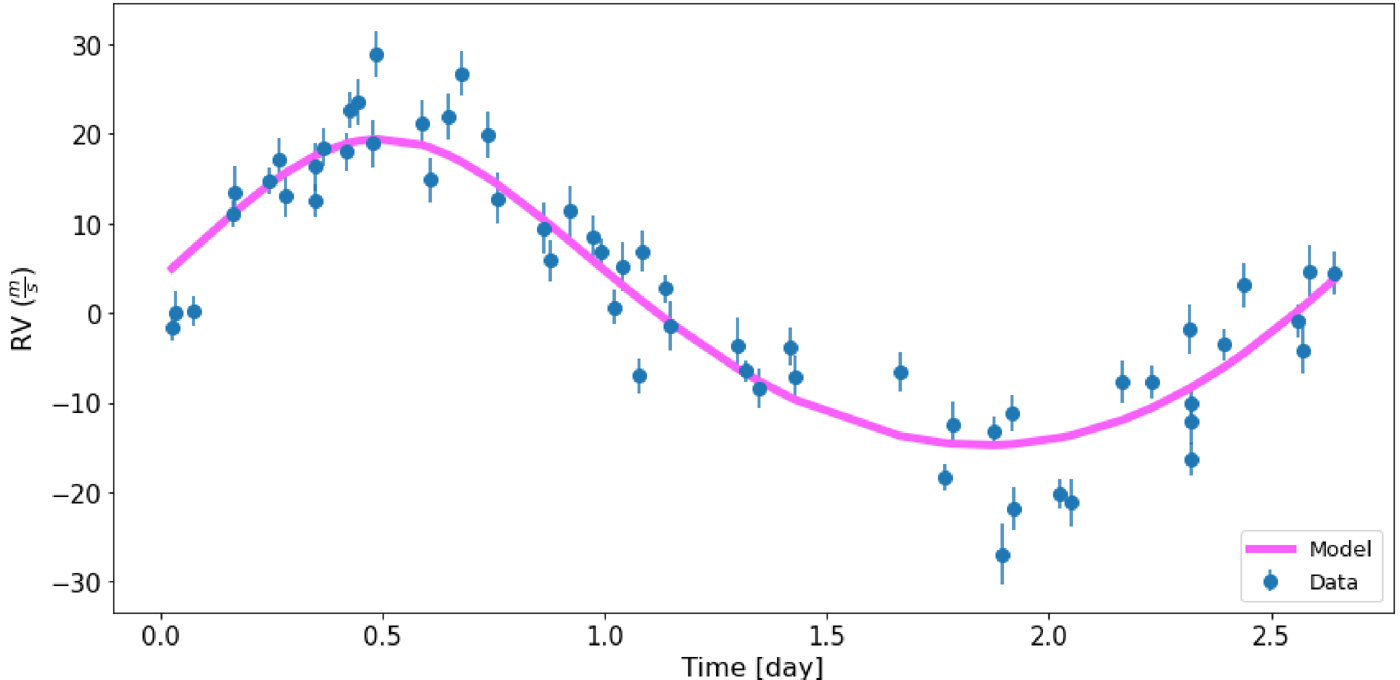
Methods (cont.)

Planet Mass

- K = Mean value of RV after one orbit
  - Semi-amplitude of RV graph
- M_p = Planetary Mass

$$K = \frac{RV_{max} - RV_{min}}{2}$$

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



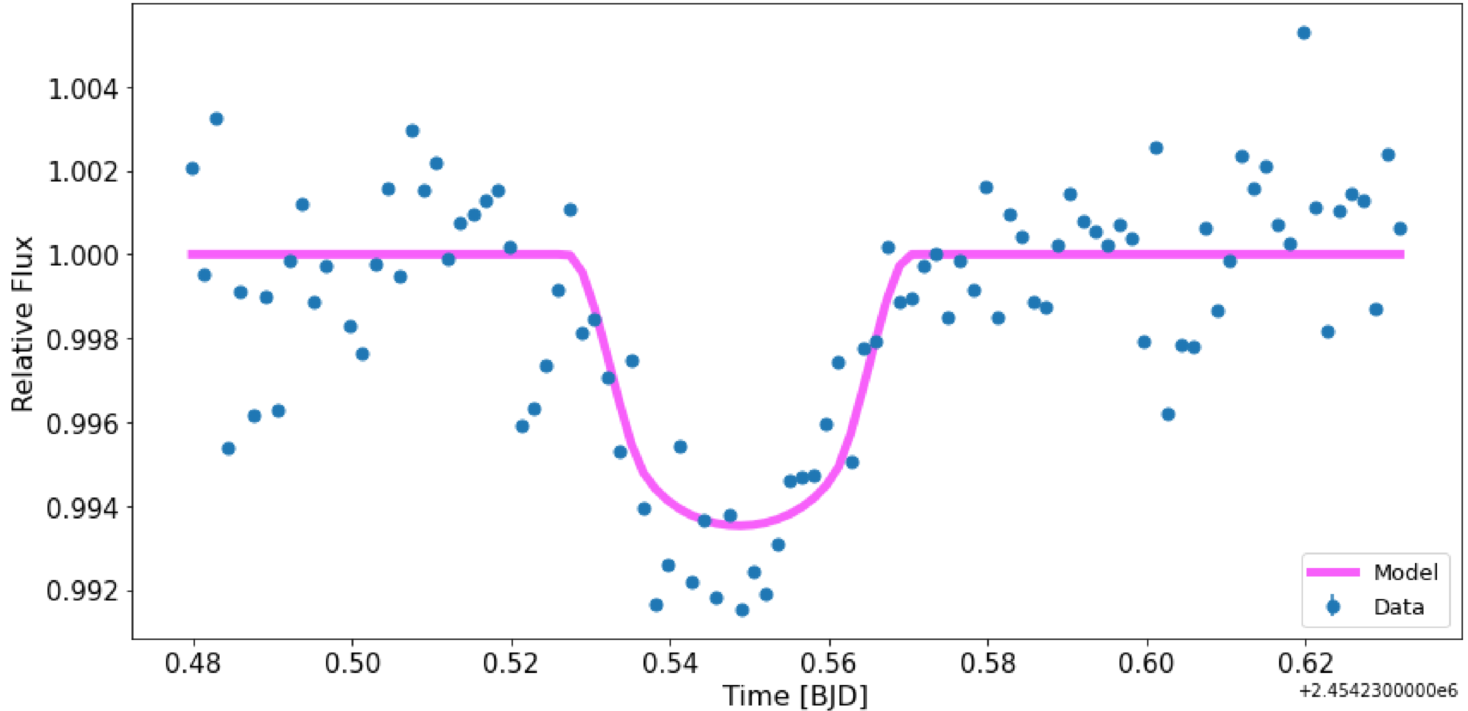
Methods (cont.)

Planet Radius

- R_p = Planetary Radius
- R_s = Stellar Radius

$$f = (\frac{R_p}{R_s})^2$$

$$R_p = \sqrt{f} \cdot R_s$$

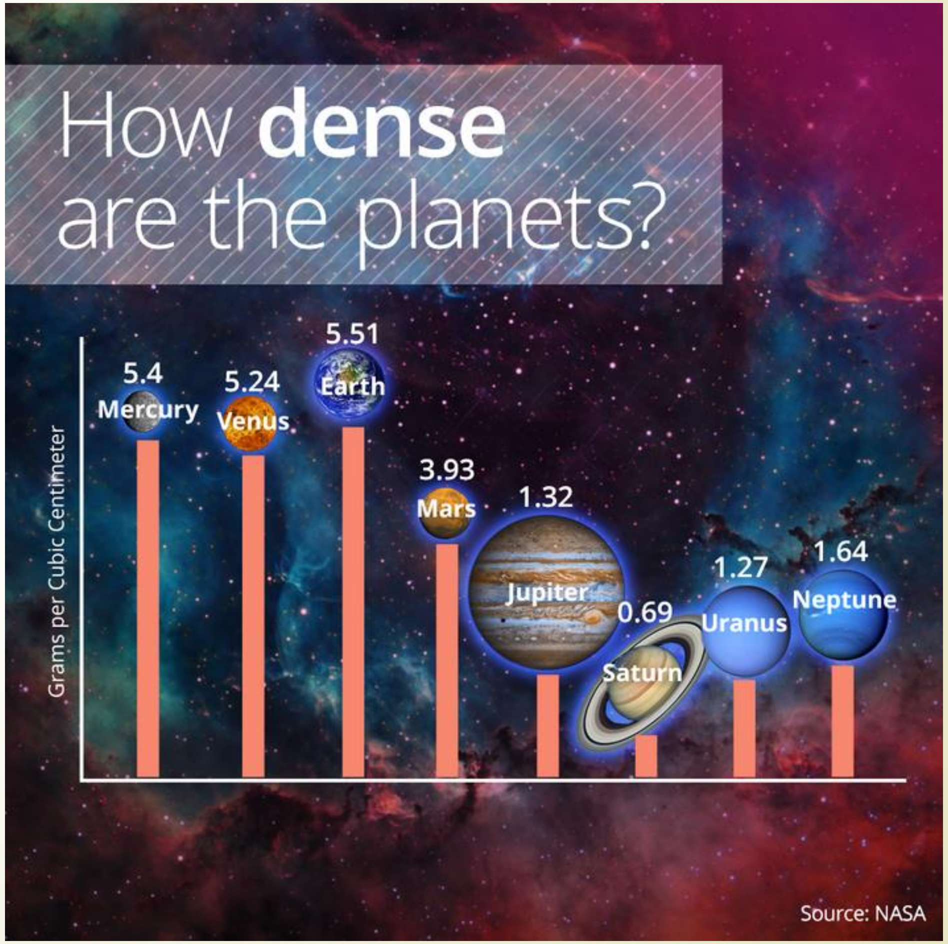


Methods (cont.)

Planet Density

- ρ = Density
  - Proportional with mass
  - Inversely proportional with radius

$$\rho = \frac{m}{(4/3)\cdot\pi R_p^3}$$



Methods (cont.)

Uncertainties

- Based on Propagation of Uncertainty

Mass:
$$\sigma_K = \frac{\sqrt{\sigma^2_{RV_{max}} + \sigma^2_{RV_{min}}}}{2} \qquad \sigma_{m_p} = \frac{\sigma_K}{\sin i} \cdot m_* \cdot \sqrt{\frac{a}{Gm_*}}$$

Radius:
$$\sigma_{R_p} = \frac{1}{2} \cdot \frac{\sigma_f}{f} \cdot R_p$$

Density:
$$\sigma_\rho = \rho \cdot \sqrt{(\frac{\sigma_{m_p}}{m_p})^2 + (\frac{\sigma_{R_p}}{R_p})^2 + (\frac{\sigma_{R_p}}{R_p})^2 + (\frac{\sigma_{R_p}}{R_p})^2}$$

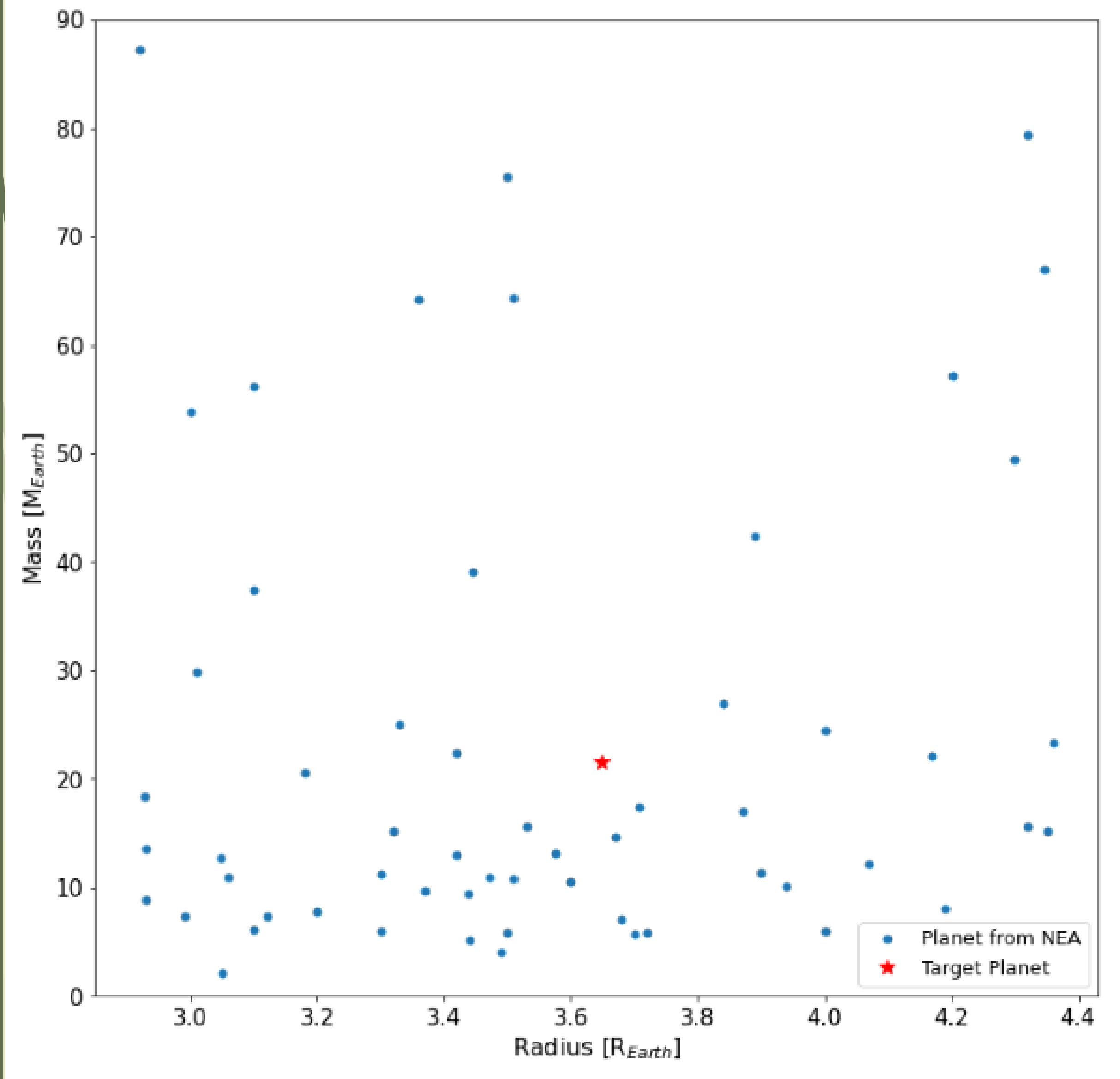
Results

Data for GJ 436 b

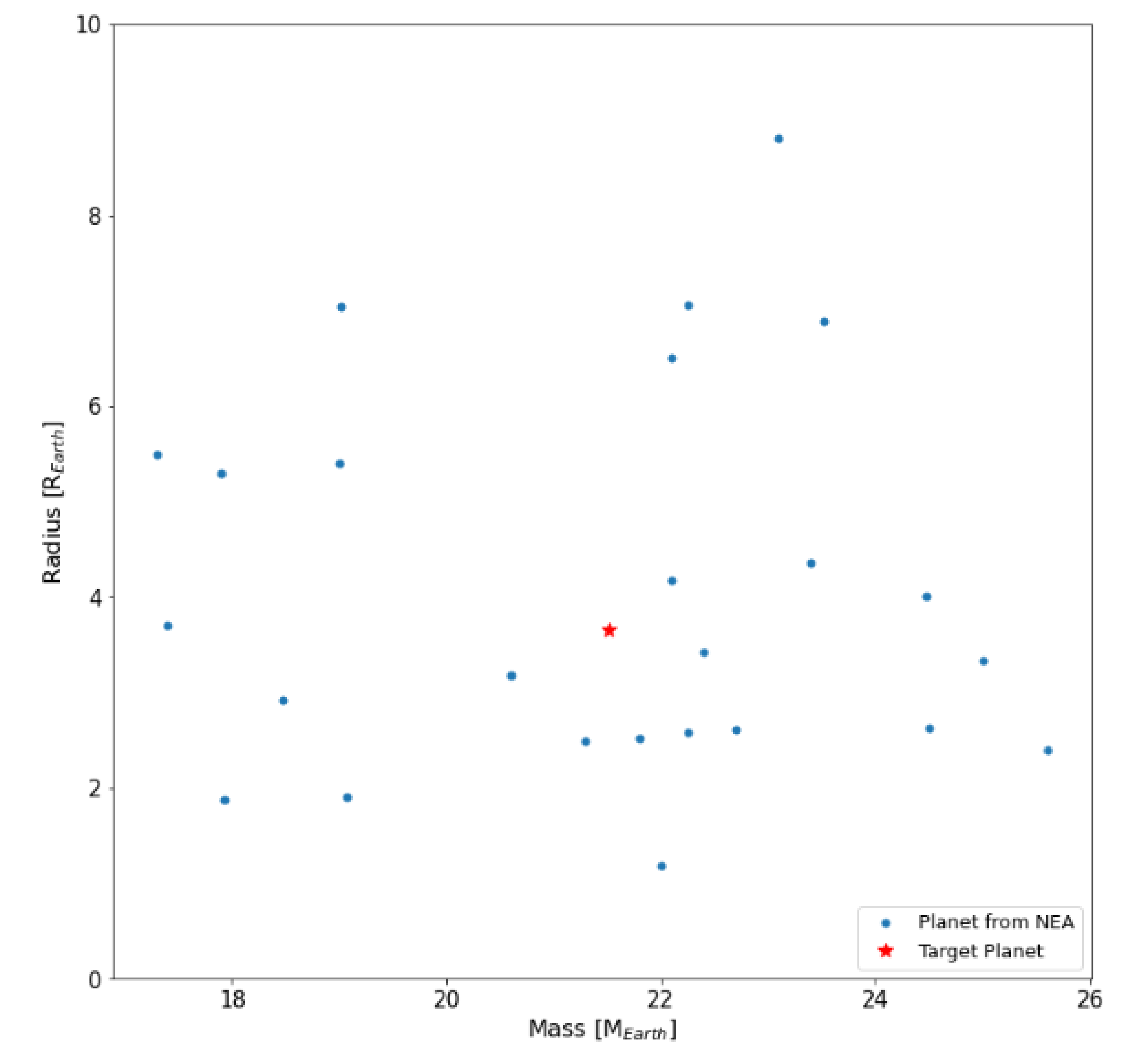
Mass:	$21.517 \pm 0.143\ M_\oplus$	0.665% Uncertainty
Radius:	$3.649 \pm 0.007\ R_\oplus$	0.192% Uncertainty
Density:	$2434 \pm 18.4\ kg/m^3$ $(2.434 \pm .0184\ g/cm^3)$	0.756% Uncertainty

Results (cont.)

More M, more D



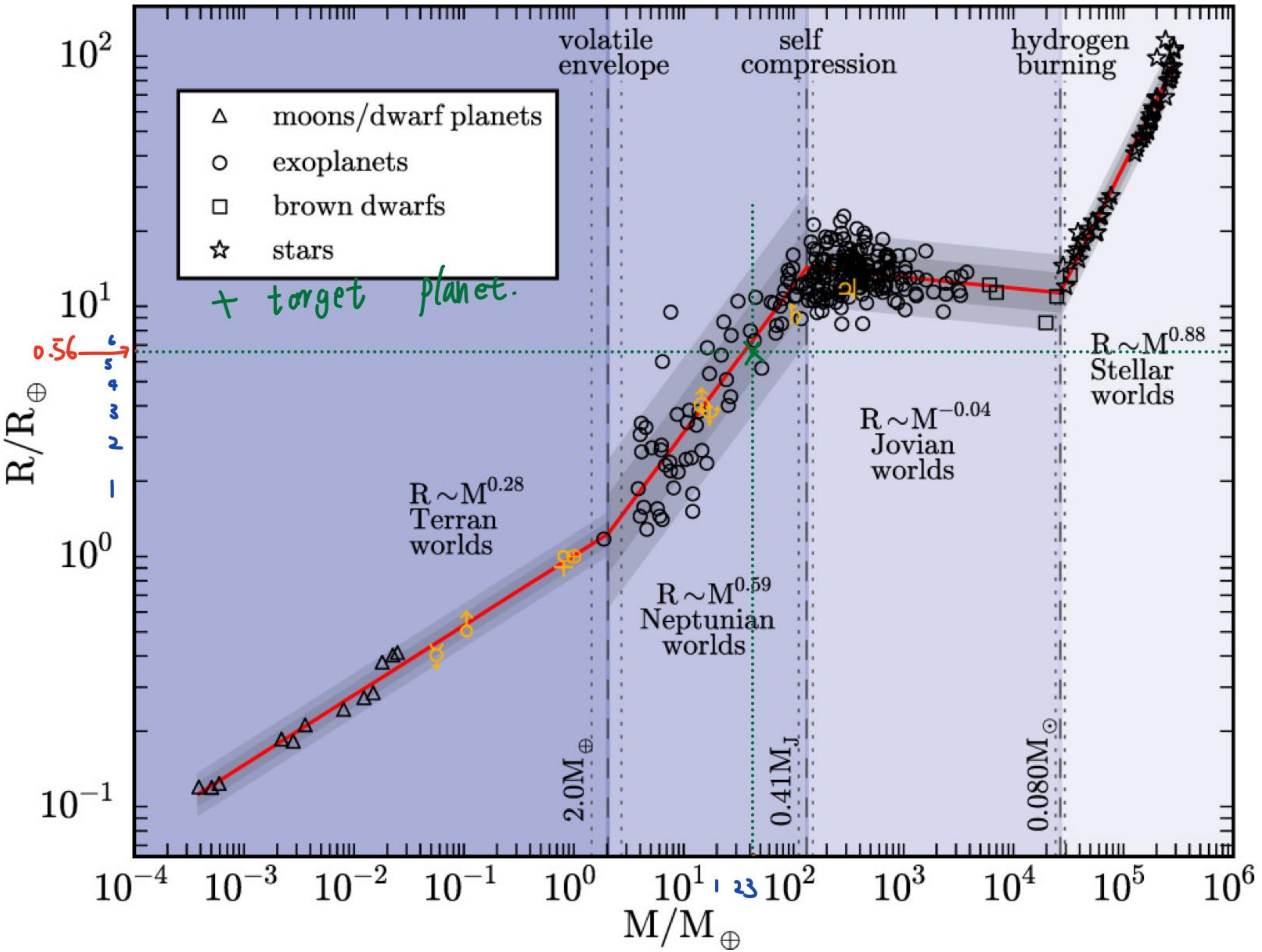
More R, less D



Results (cont.)

$$21.516889 M_\oplus = 10^{1.333} M_\oplus$$

$$3.6487376 R_\oplus = 10^{0.562} R_\oplus$$



M-R relation from Chen & Kipping (2016)

Conclusion

Results for GJ 436 b:

- Is a Neptunian world with similarities to Neptune
- Has an Earth Mass of ~21.517 & Earth Radii of ~3.649
- Less dense than Earth but more dense than all solar system gas giants
- High certainty with the radius calculation
- The benefits from radial velocity and transit detection