Intro to Astronomy – Exoplanet Detection Methods Homework

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Course: Intro to Astronomy

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Due Date: July 15, 2025

Assignment: Exoplanet Characterization – GJ 8999 b

(a) What is the inclination of GJ 8999 b?

Since we observe transits of GJ 8999 b, the inclination of the planet's orbit must be nearly edge-on with respect to our line of sight. For a planet to transit its host star, the inclination angle i must be close to 90°. While precise values depend on impact parameter and orbital radius, the fact that we see a transit implies:

$i \approx 90°$

Thus, the inclination of GJ 8999 b is **approximately 90 degrees.**

(b) What is the period of this exoplanet?

Referring to Figure 1, we observe four evenly spaced dips in stellar flux over a 28-day time span. Therefore, the time between each transit (i.e., the orbital period P) is:

$P = 28 \text{ days} / 4 = 7 \text{ days}$

So, the orbital period of GJ 8999 b is **7 days.**

(c) What is the radius of this planet?

From Figure 2, the transit depth (i.e., fractional decrease in flux) is approximately 1%, or 0.01. Since the transit depth δ is related to the square of the ratio of planet radius Rp to stellar radius R*:

$\delta = (Rp/R^*)^2 \rightarrow Rp/R^* = \text{sqrt}(0.01) = 0.1$

Given $R^* = 0.2\ R\odot \rightarrow Rp = 0.1 \times 0.2\ R\odot = 0.02\ R\odot$

$0.02\ R\odot = 13{,}927 \text{ km} \rightarrow Rp \approx 2.2\ R\oplus$

So, the radius of GJ 8999 b is approximately **2.2 Earth radii.**

(d) What is the semi-amplitude K of this planetary signal?

From Figure 3, the radial velocity curve has a peak-to-peak amplitude of about 30 m/s. The semi-amplitude K is half of that:

$K = 30 \text{ m/s} / 2 = 15 \text{ m/s}$

Therefore, **K = 15 m/s.**

(e) What is the mass of this planet?

Using the simplified RV formula and assuming sin(i) ≈ 1:

$M_p \approx (K / 0.09\ m/s) \times (P / 1\ yr)^{(1/3)} \times (M^*/M\odot)^{(2/3)}\ M\oplus$

$= (15 / 0.09) \times (7 / 365)^{(1/3)} \times (0.2)^{(2/3)} \approx 14.8\ M\oplus$

Thus, the mass of GJ 8999 b is **approximately 15 Earth masses.**

(f) What is the composition of GJ 8999 b?

Using the estimated radius (2.2 R⊕) and mass (15 M⊕), the values fall between the "pure rock" and "50% rock, 50% water" curves in the mass-radius diagram, leaning toward the rocky side.

This suggests GJ 8999 b has a **rocky core with a volatile-rich envelope, likely a water-rich sub-Neptune or mini-Neptune.**

Conclusion

GJ 8999 b is a short-period exoplanet orbiting a small M-dwarf star with:

- Orbital Period: 7 days
- Radius: ~2.2 Earth radii
- Mass: ~15 Earth masses
- Composition: Likely a water-rich planet or mini-Neptune

Its characteristics place it in a category suitable for future atmospheric studies.

FIGURES

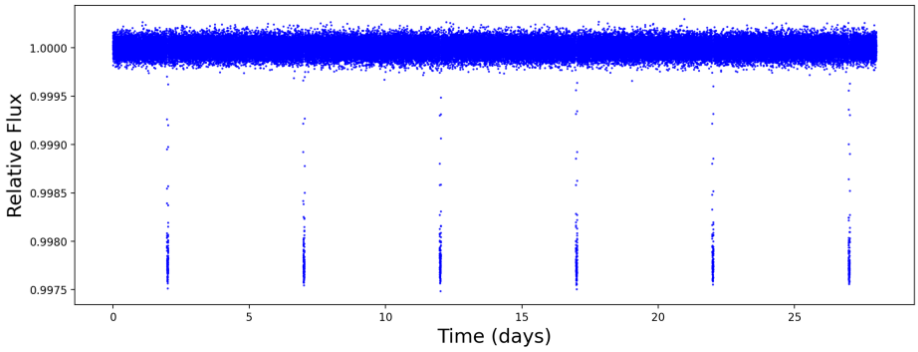

Figure 1. A plot of the flux of GJ 8999 over time over a 28-day period.

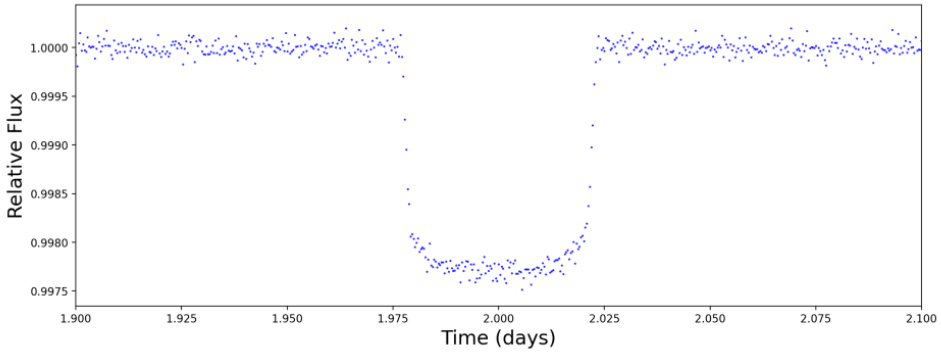

Figure 2: A plot of the flux of GJ 8999 over time, zoomed into a single exoplanet transit.

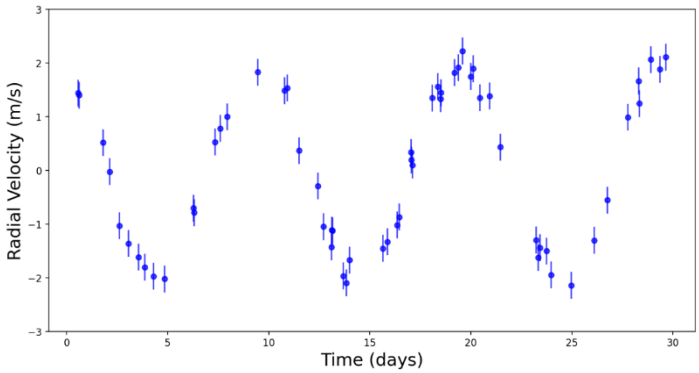

Figure 3: A plot of the radial velocity of GJ 8999 over time.

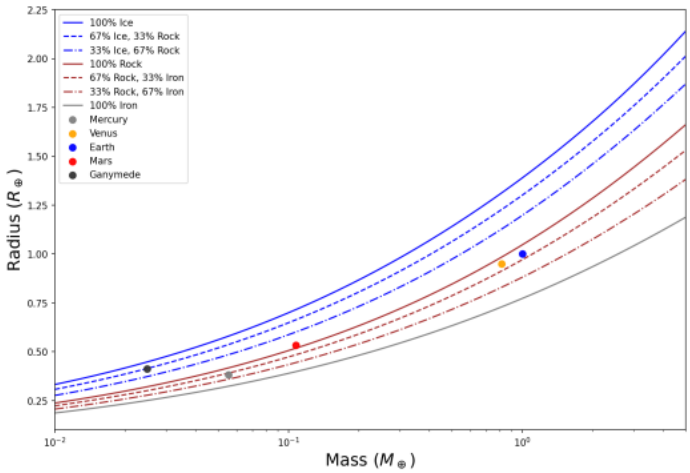

Figure 4: A plot showing the mass-radius curves for different exoplanet compositions.