Exoplanet Detection

and finding Jupiter-like planets around Sun-like stars

Kevin Hoy, Joshua Kingsbury, Avidaan Srivastava, Logan Steele

Motivation

Detecting exoplanets helps us understand the possibilities of planet formation

However, there is a need for a variety of detection methods as not all systems have the same observables and some require very specific conditions.

Lastly, we can figure out what detection methods are most suited for different kinds of planets so that we may utilize these methods for the best detections.

Methods: Radial Velocity

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

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

Assuming sin(i)=1 for an edge-on disk

The current state-of-the-art value for this radial velocity semi-amplitude, K, is 0.5 m/s with a 0.5 M_{sun} mass detection limit

Methods: Transit

$$f = \left(\frac{R_p}{R_*}\right)^2$$

$$SNR = \frac{\delta}{\sigma_{CDPP}} \times \sqrt{\frac{n_{tr} t_{dur}}{b}}$$

State-of-the-art transit depth sensitivity is given by K2 is $\boldsymbol{\sigma}$ = 12 ppm.

For K2, SNR = 9.

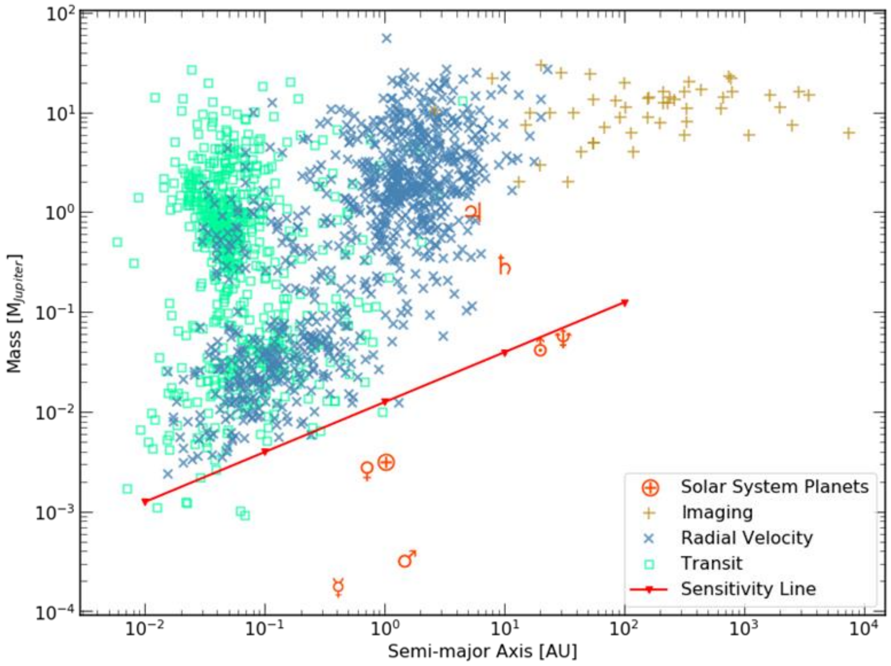
Methods: Direct Imaging

$$\frac{L_p}{L_*} = p * \varphi * \left(\frac{R_p}{a}\right)^2 + \frac{R_p^2}{R_*^2} * \frac{e^{\frac{hc}{\lambda k_B T_*}} - 1}{e^{\frac{hc}{\lambda k_B T_p}} - 1}$$

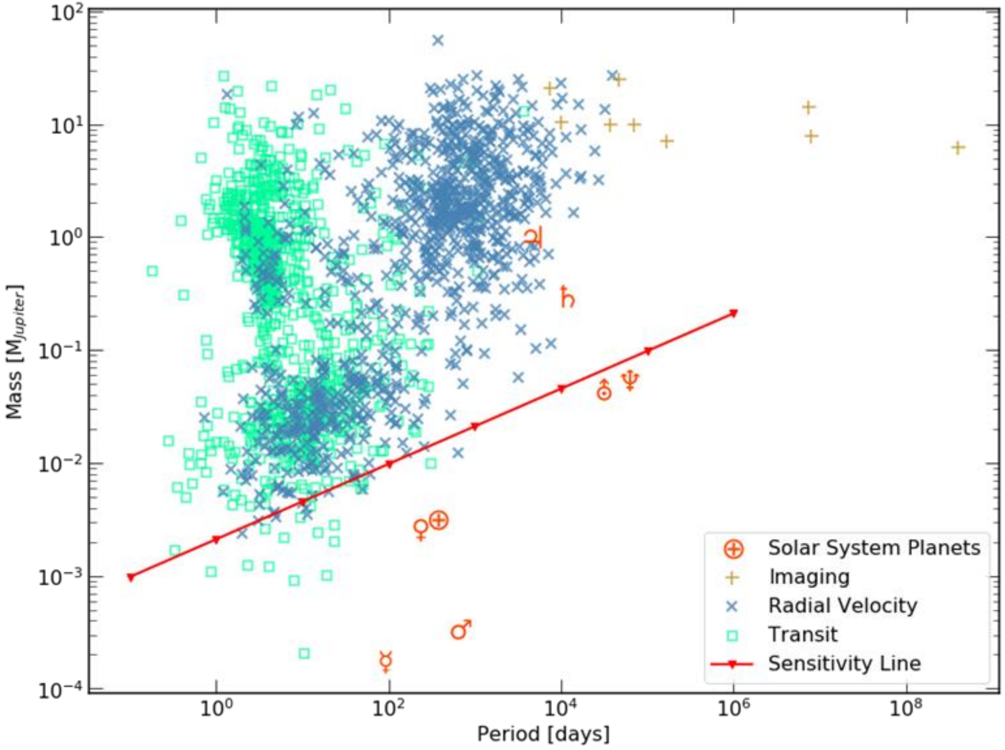
$$\theta \sim 1.22 \frac{\lambda}{D}$$

The state-of-the-art signal contrast from the TMT Second Earth Imager is a minimum of 8 * 10^{-8} at 0.01 arcseconds.

Results: Radial Velocity Method

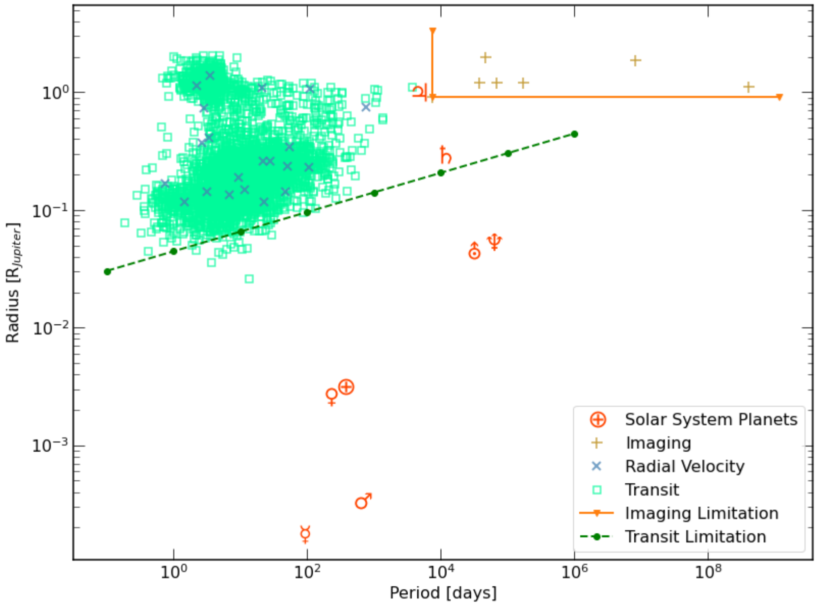


For a Jupiter-like planet around a Sun-like star: K = 12.46 m/s



Mass [M$_{Jupiter}$]
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^0
10^2
10^4
10^6
10^8
Period [days]
Solar System Planets
Imaging
Radial Velocity
Transit
Sensitivity Line

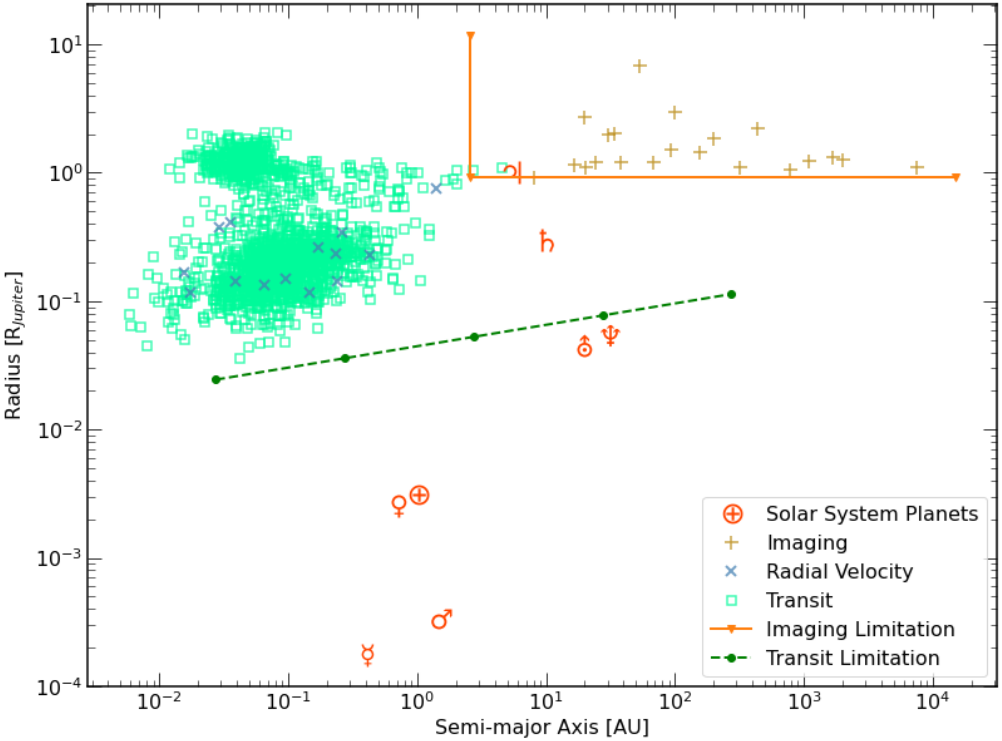
Results: Transit Method



With the state of the art sensitivity of K2 is at 12 ppm.

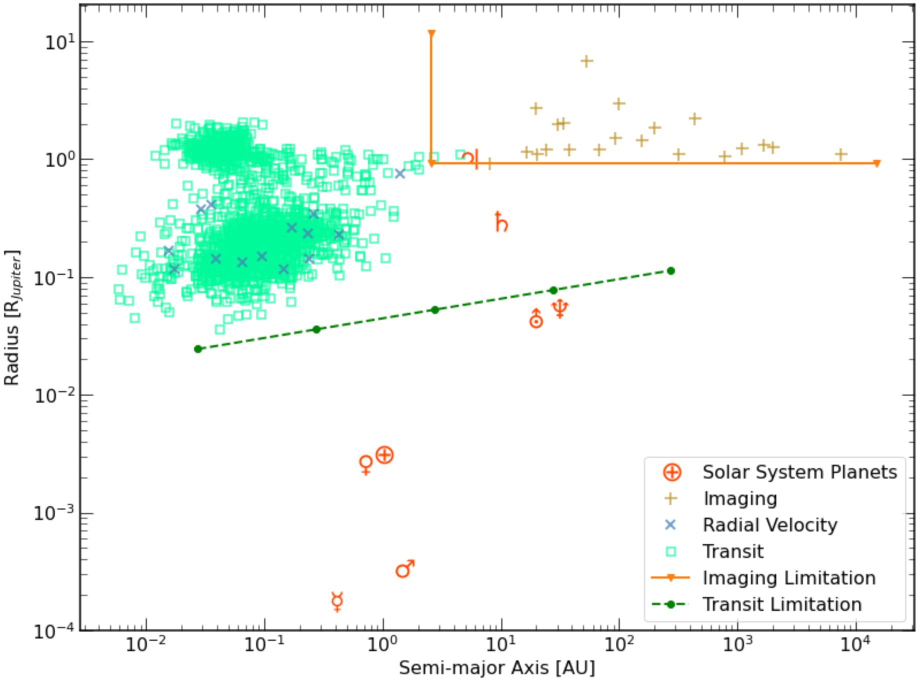
Able to detect a planet down to 1/30 R_j around a Sun-like star

SNR = 278 for a Jupiter like planet around a Sun-like star



Radius [$R_{Jupiter}$]
Semi-major Axis [AU]
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Solar System Planets
Imaging
Radial Velocity
Transit
Imaging Limitation
Transit Limitation

Results: Direct Imaging



With the assumption of a constant geometric albedo and the phase is π/2,

Jupiter's signal at peak emission (23 microns) = 10^{-6} which fall within range of the Second Earth Imager instrument.

Conclusions

Radial velocity: Can easily detect a Jupiter-like planet

Transit: Can easily detect a Jupiter-like planet

Direct Imaging: Can only be detected out to 9pc with state-of-the art

Contributions

Kevin Hoy: Analysis of Direct Imaging detection method

Joshua Kingsbury: Analysis of Transits detection method

Avidaan Srivastava: Writing of the report

Logan Steele: Analysis of Radial Velocity detection method and in-class presentation

Questions?