Journal of Physics Special Topics
An undergraduate physics journal

P1_5 The View of the Sun from Alien Worlds

T. Hyde, J. Cowen, T. Johnstone, G. Sutlieff, P. Doyle

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

December 6, 2018

Abstract

In this paper, we estimate whether the planets of the Solar System would be detectable by a theoretical extraterrestrial civilisation with a level of technology similar to present day Earth. We found that only Jupiter, Earth, and Venus could have been detected already, while Saturn, Uranus and Neptune would be detectable in the future.

Introduction

At the time of writing, the vast majority of confirmed planets outside the Solar System have been detected by either the transit photometry method, or the Doppler spectroscopy (or radial velocity) method [1]. These are both are indirect methods of detection, as the majority of planets cannot be seen through the glare of their host star. Most of the discussion on the detection of extraterrestrial life focuses on how we could detect its presence with our own technology.

In this paper, we discuss which planets of the Solar System could be detected with existing radial velocity techniques, by a hypothetical extrasolar civilisation with a level of technology equivalent to present day Earth. This is a general study of the detectability, and we are not considering any specific observer.

Background

The radial velocity method can find an extrasolar planet's radius, semi-major axis, and orbital period by observing the spectrum of its host star. Every planet orbiting a star causes the star to 'wobble' slightly as both orbit a shared centre of mass. This movement causes a Doppler shift in the emission spectrum of the star, which can be observed with a sufficiently sensitive spectrograph. To find the mass of an exoplanet, knowing its orbital velocity and the mass of the star, we would use [2]

$$M_{PL} = \frac{M_{star} V_{star}}{V_{PL}} \tag{1}$$

where M is the mass and V is the orbital velocity of the planet (PL) or star. In our case, we already know the mass of each planet, so we simply use the same equation to find the component of the Sun's radial velocity (V_{star}) due to the planet's influence. This is in fact the maximum observed velocity, as the actual observed velocity, K is given by $K = V_{star} \sin i$ [2], where i is the inclination of the planet's orbit with respect to a line perpendicular to the line-of-sight (so that the maximum velocity is observed when viewed along the orbital plane).

We can then estimate the 'detectability' of the planet by various spectrographs, described in Table 1, with data from [3], [4], [5]. The 'sensitivity' is a rough estimate of the error on their radial velocity measurements; any movements much smaller than this would not be detected.

Table 1: Stellar Spectrographs

Spectrograph	Sensitivity (ms^{-1})	Date of Installation
ELODIE	7	1993
HARPS	0.3	2003
ESPRESSO	0.1	2017

Finally, we must take into account that, to confirm the detection of a planet, it must be observed over at least one full orbit.

Results

The results are shown in Table 2. Planetary values are from NASA [6], with the velocities converted from kmh^{-1} to ms^{-1}. We used a value of 1.989×10^{30} kg [7] for the mass of the Sun. The year given in brackets is when these planets will first be detectable by existing spectrograph technology, by adding the orbital period to the date of the relevant spectrograph's installation.

Conclusion

From the results in Table 2 we can conclude that an extraterrestrial civilisation with Earth's level of technology would only be able to definitively confirm the presence of Jupiter, and possibly Earth and Venus. These have radial velocities just slightly below the error of the ESPRESSO spectrograph, so may be detectable, but may be difficult to confirm—no errors were given for the NASA values. We rounded most of these values to a few significant figures, so there is some uncertainty in the result for V_{Star}, and Venus and Earth are close enough to the threshold that they could be detectable. Saturn, Uranus, and Neptune would be detectable in theory, but the length of their orbits means more time would be needed to confirm their presence.

From the planets deemed 'detectable', this method gives us only their orbital period, semi-major axis, and mass. A different method, such as transit photometry, would be required to estimate their size (and hence density).

Further study could be done to estimate how these planets could be detected by other exoplanet detection methods.

References

[1] http://www.planetary.org/explore/space-topics/exoplanets/how-to-search-for-exoplanets.html [Accessed 04 Dec. 2018]

[2] 'A demonstration device to simulate the radial velocity method for exoplanet detection', W Choopan et al 2016 Phys. Educ. 51 044001

[3] http://adsabs.harvard.edu/abs/1996A%26AS..119..373B [Accessed 04 Dec. 2018]

[4] http://www.eso.org/sci/facilities/lasilla/instruments/harps/science/papers/harps_mess114.pdf [Accessed 04 Dec. 2018]

[5] https://www.eso.org/sci/facilities/paranal/instruments/espresso/overview.html [Accessed 04 Dec. 2018]

[6] https://solarsystem.nasa.gov/planet-compare/ [Accessed 04 Dec. 2018]

[7] http://astronomy.swin.edu.au/cosmos/S/Solar+Mass [Accessed 04 Dec. 2018]

Table 2: Detectability of Solar System planets

Planet	M_{PL} (kg)	V_{PL} (ms^{-1})	V_{star}	Orbital period (Earth years)	Detectability
Mercury	330.1×10^{21}	47362	0.0079	0.2	No
Venus	4.867×10^{24}	35020	0.086	0.6	Potentially (2018) (ESPRESSO)
Earth	5.972×10^{24}	29783	0.089	1	Potentially (2018) (ESPRESSO)
Mars	0.641×10^{24}	24077	0.0078	1.9	No
Jupiter	1.898×10^{27}	13056	12.5	12	Yes (2005) (ELODIE)
Saturn	0.568×10^{27}	9639	2.75	30	Yes (2033) (HARPS)
Uranus	8.861×10^{25}	6799	0.303	84	Yes (2087) (HARPS)
Neptune	1.024×10^{26}	5435	0.28	165	Yes (2168) (HARPS)