Re-examining the radial velocity detection of L98-59b

Executive Summary

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Introduction The radial velocity (RV) method, also known as Doppler spectroscopy is an indirect method of exoplanet detection via shifts in the spectrum of a planet's parent star. This method is responsible for the first convincing exoplanet discovered around a Sun-like star with a mass similar to Jupiter. Since this discovery, exoplanet detection has exploded as a field, motivated by the search for Earth- like planets outside the Solar System.

Developments in telescopes such as HARPS and ESPRESSO have allowed us to locate many terrestrial, Earth-like planets. Most notably the lowest mass planet measured so far using RVs: L98-59b, a rocky planet with half the mass of Venus. If confirmed, this planet will sit in the middle of the habitable zone of the L98-59 system. These results represent an important achievement in the quest for life outside the Solar System.

Detecting low-mass planets using indirect methods like the RV method are however challenging due to strong stellar signals from the planet's parent star. To account for the stochastic nature of stellar activity we utilise Gaussian processes (GPs). GPs allow us to derive the stochastic nature of stellar activity from data points, which performs much better than trying to parameterise stellar activity.

This study re-examines the L98-59 system, specifically L98-59b using a GP framework to refine and understand the characteristics and orbital dynamics of this Earth-like planet.

Project Significance The investigation of L98-59b is crucial due to its unique position as one of the lightest exoplanets detected via radial velocity methods. Additionally L98-59b is an Earth-like planet that sits in the middle of the habitable zone of the L98-59 system. This results represent an important achievement in the quest for life outside the Solar System.

Furthermore, L98-59b is situated in a system with two other transiting planets, this study offers insights into the dynamics and compositions of closely-packed terrestrial planets, advancing our understanding of their formation and evolution in a shared stellar environment.

Methods Our approach integrates a multi-components model with observational data from HARPS and ESPRESSO. The compliments include:

i Planetary Dynamics-utilising Keplerian dynamics to model the interactions within the three-planet system.

ii Instrumental Adjustment-correcting for data offsets when simultaneously modelling observational data from more than one instrument.

iii Stellar Activity-implementing a GP framework to account for chromospheric activity and other noise factors, which are critical in isolating genuine planetary signals from stellar variability.

Results The study confirmed the presence of planet L98-59c and suggested the existence of L98-59b, aligning closely with its hypothesised parameters.

Conclusion While L98-59b's detection remains tentative, our refined modelling approach using GPs has demonstrated promising capabilities in distinguishing planetary signatures from stellar noise and marks an enhanced the framework for analysing such low-mass exoplanets.

Future Work Future efforts will focus on further constraining these models, incorporating multi-dimensional GPs to better handle the complexities of stellar noise and planetary signals and extend our to incorporate atmospheric considerations from recent transit surveys. This continued research is expected to solidify the detection of L98-59b and potentially reveal more about Earth-like exoplanets.

Implications This work not only progresses the field of exoplanet detection but also provides a robust framework for future studies aiming to detect and analyse Earth-like planets in other solar systems. The methodologies and insights from this research can significantly impact the strategies employed in upcoming explanatory missions and the broader search for habitable worlds beyond our solar system.