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Supplementary information

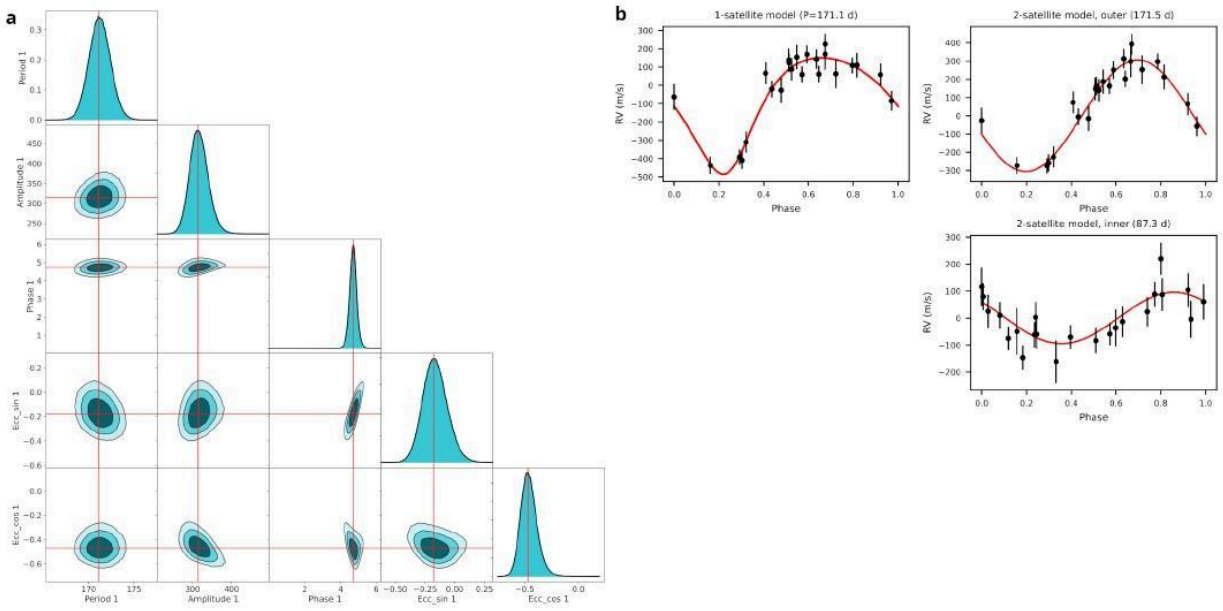
Planetary-mass exosatellite detected around the substellar companion of a star

In the format provided by the authors and unedited

Supplemental Information

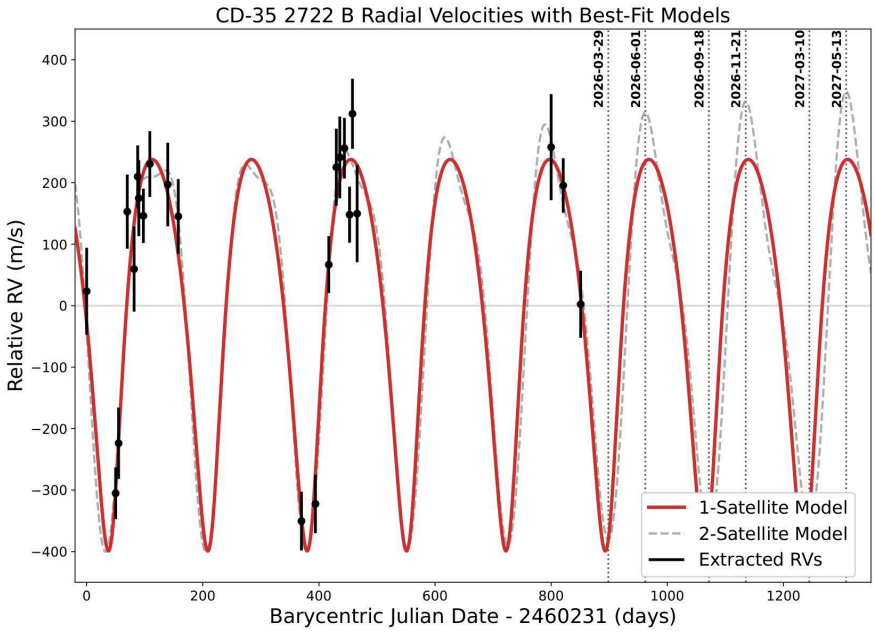
1. Extra Orbital Fitting Figures

Extended Data Figure 7:



This figure contains extra plots related to the orbital fitting, including the MCMC corner plot (left) and the phase-folded RV over time plots for both best-fitting models (right).

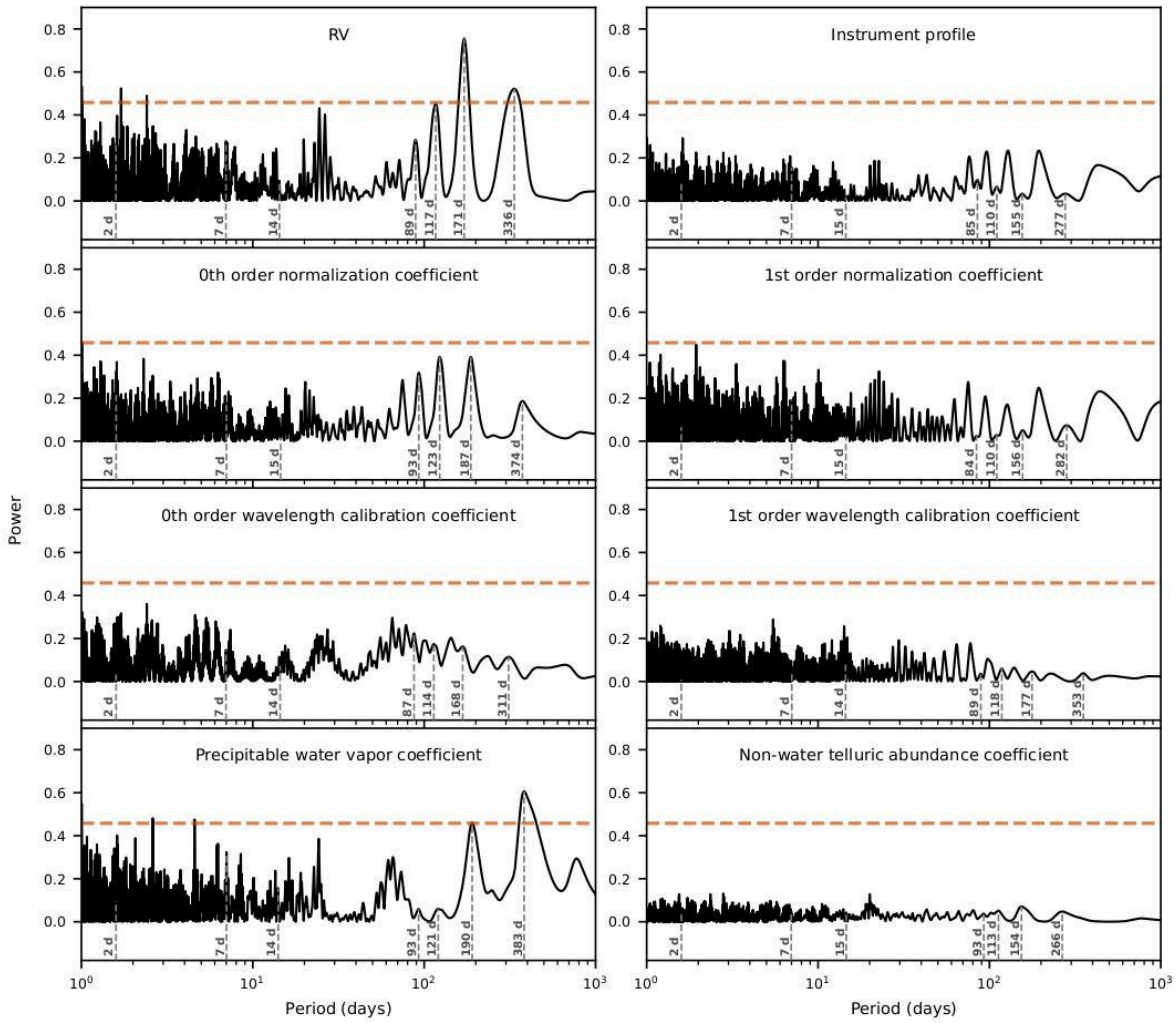
Extended Data Figure 8:



Best-fitting models projected into the future, marking epochs of strong differentiation between the 1- and 2-satellite models. This can be used to plan future observations to better constrain the orbit(s) and resolve the model degeneracy.

2. Other Potential Periodicities

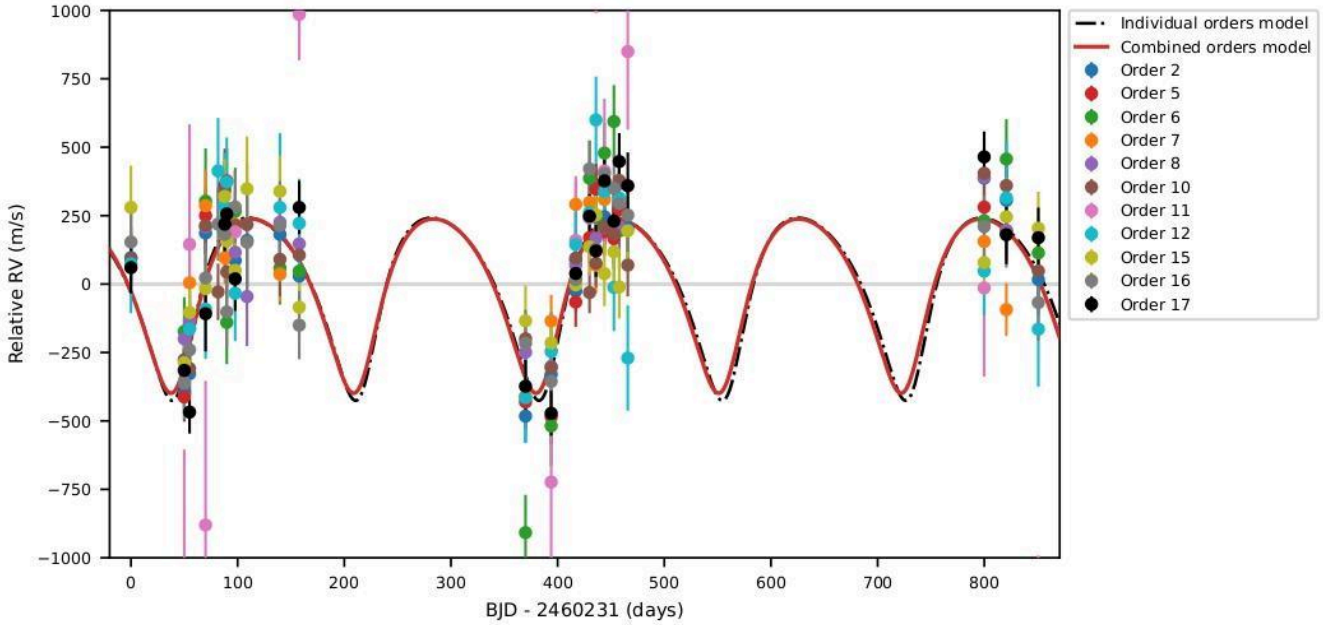
Extended Data Figure 9:



We compared our RV results to GLS periodograms made using the model parameters fit by viper in conjunction with the RVs, to see if they shared any periodicity with the RVs themselves. No correlation can be found, with no significant periodicities present in these parameters, and even the insignificant peaks do not align with the derived periods of the satellites. These periodograms are shown here. Specifically, the "instrument profile" periodogram could be influenced by the rotation of the target. We assume that the primary contributor to the line profile is instrumental, hence the name, but it is theoretically possible that if there are real changes in the line profile of the object, they would manifest here. However, no periodicity is recovered for this variable, meaning it is unlikely for rotational modulation of line profiles to be a significant driver of the RV variation. Of these periodograms, the one with the strongest peaks is the one for precipitable water vapor, but those peaks are much nearer to an Earth year and its aliases, denoting seasonal weather cycles, rather than the periods of our proposed satellites.

3. Individual Order RVs

Extended Data Figure 10:



We also performed an orbital fit in which we do not combine the RV values from the eleven included spectral orders. We bin the RV values for each order across the two nodding frames, but leave each order as a separate measurement, giving us 11 measurements in a given night. Individually, these points have significantly higher errors than the combined points used for the main analysis. However, by leaving them separate, we can see if there exists any order with especially low errors that may be too heavily weighted, driving the fit, or if the points are distributed about mean values which continue to show periodicity. In this case, the latter appears to be correct, as we are able to recover an almost identical best-fit model which the orders are dispersed about. The only significant difference between the models is a slightly amplified eccentricity in the individual-orders case, which is 0.3 instead of 0.27. Both models can be seen here, along with these order-separated points. In this plot, it can be seen that Order 11 is relatively unstable. Despite this, we include it in the main analysis because it is still stable compared to those orders we have excluded, and we prefer to err on the side of caution and include as many orders as possible. This order's high error measure mitigates its effect on the weighted binning, in any case.