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A double-blind study of detection and characterization of planetary systems by astrometry and RV measurements

Joseph Catanzarite (1), Wesley Traub (1), Valeri Makarov (2), and Michael Shao (1)
(1) Jet Propulsion Laboratory/California Institute of Technology, (2) California Institute of Technology

Introduction

Astrometry from space will make extremely precise stellar position measurements, at angular precision below 1 micro-arcsecond (uas) per visit. Hundreds of visits over five years could achieve a relative astrometric precision of below 0.035 uas, well below the astrometric signature of 0.3 uas for a Sun-Earth system at 10 pc. Future ground-based radial velocity (RV) instruments will have precision of 10 cm/s, comparable to the Earth's RV signature.

The statistics of exoplanet detections by radial velocity show that multiple-planet systems are common. Though the frequency of Earth analogs remains to be determined from Kepler data, gound-based microlensing studies already suggest that 10 to 15% of stars have planetary systems with gas giants like our own.

A future space-based astrometric mission to detect Earth analogs at nearby stars, such as the SIM Lite Astrometric Observatory, will benefit from prior ground-based RV datasets with long time baselines. The RV observations allow the identification of long-period gas-giant planets.

We report on a double-blind experiment demonstrating that such a combination of astrometric and RV surveys could successfully untangle the multiple-planet systems (including those like our own) that we expect to find.

Structure of the experiment

The experiment involved four teams of scientists. Dynamicists (Team A) produced a database of hundreds of simulated multiple-planet systems consistent with observational knowledge and theoretical expectations. Data generators (Team B) perturbed 60 planetary search target stars with planetary systems selected at random from this database. Adopting realistic observing schedules with solar exclusion gaps, and adding measurement noise, they produced simulated astrometric and RV observation data sets for each of the 60 systems. At each target star, the integration time for astrometry was sufficient to detect an Earth mass planet in the habitable zone. Analysts (Team C) were given only the observation data sets, with the task of solving for the planetary masses and orbit parameters. They submitted their answers to the Evaluators (Team D), who compared them to truth and scored them for completeness and reliability.

Results

A key finding is that with high-precision astrometry supplemented by ground-based RV measurements, planets in multiple planet systems can be detected and characterized nearly as effectively as isolated planets. Moreover, the presence of multiple planets does not significantly degrade the detectability of Earth-like planets in the habitable zone.

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