# Bayesian methods for exoplanet science: Planet detection, orbit estimation, and adaptive observing

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In the last decade astronomers have discovered about 300 planetary systems around nearby stars; new systems are announced almost weekly and the pace of discovery is accelerating. The data are now of sufficient quantity and quality that exoplanet science is shifting from being discovery-oriented to focusing on detailed astrophysical modeling and analysis of the growing catalog of observations. Making the most of the data requires new statistical tools that can account for diverse sources of uncertainty in the context of complex models.

In this talk I will describe work in progress by a collaboration of astronomers and statisticians developing a suite of Bayesian tools for exoplanet detection, planetary orbit estimation, and adaptive scheduling of observations. This work focuses on analysis of stellar reflex motion data, where a planet is detected by observing the "wobble" of its host star as it responds to the gravitational tug of the orbiting planet. Kepler's laws specify an analytical model for the resulting time series, but it is strongly nonlinear, yielding complex, multimodal likelihood functions. The parameter spaces range in size from few-dimensional to dozens of dimensions, depending on the number of planets in the system, and the type of motion measured (line-of-sight velocity, or position on the sky). Since orbits are periodic, Bayesian generalizations of periodogram methods facilitate the analysis. This relies on use of interim priors to enable analytical dimensional reduction of the model. Subsequent analysis uses adaptive MCMC methods and adaptive importance sampling to perform the integrals required for both inference (planet detection and orbit measurement), and information-maximizing sequential design (for adaptive scheduling of observations).