Thesis abstract

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The Gaia space observatory has produced astrometric measurements of extraordinary precision, enabling detection of exoplanets through the reflex motion of their host stars. With Gaia Data Release 4 (DR4) scheduled for December 2026, which will include full epoch astrometry, methods for orbital parameter recovery are needed. This work presents a Bayesian Markov Chain Monte Carlo (MCMC) framework for fitting astrometric orbits to Gaia epoch data, applied to five Gaia DR3 candidates with distinct orbital configurations. With real epoch astrometry data not yet publicly available, observations are simulated based on published Gaia orbital solutions, using conservative per-epoch noise of $\sigma_{AL} = 0.1$ mas, for both five-year and ten-year mission scenarios.

The framework successfully recovers orbital parameters for all five candidates, with the ten-year mission generally providing improved precision over the five-year mission, particularly for lower signal-to-noise systems. Injection-recovery tests demonstrate reliable period and eccentricity recovery across wide parameter ranges. An overestimation of inclination is identified for nearly face-on orbital configurations, consistent with a known mathematical consequence of the back-conversion from Thiele-Innes to Campbell elements. Period perturbation sweeps reveal the presence of period aliases at the 2:1 and 3:2 mean-motion resonance periods, highlighting the need for careful treatment when interpreting real DR4 detections. Additionally, one candidate has independently been identified as a false positive, demonstrating the importance of follow-up observations for solely astrometrically detected companions. The method will be directly applicable to real DR4 epoch data with no fundamental modifications, and the results support the scientific case for GaiaNIR as a potential successor mission with an extended observational baseline.