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HIGH-ORDER RESONANT ORBIT MANIFOLD EXPANSIONS FOR MISSION DESIGN IN THE
PLANAR CIRCULAR RESTRICTED 3-BODY PROBLEM**Abstract**

In recent years, stable and unstable manifolds of invariant objects (such as libration points and periodic orbits) have been increasingly recognized as an efficient tool for designing transfer trajectories in space missions. However, most methods currently used in mission design rely on using eigenvectors of the linearized dynamics as local approximations of the manifolds. Since such approximations are not accurate except very close to the base invariant object, this requires large amounts of numerical integration to globalize the manifolds and locate intersections.

The goal of this paper is to study hyperbolic resonant periodic orbits in the planar circular restricted 3-body problem, and transfer trajectories between them, by: 1) determining where to search for resonant periodic orbits; 2) developing efficient and accurate methods for computation of their invariant manifolds; and 3) developing an algorithm to compute intersections of the stable and unstable manifolds. We develop and implement algorithms that accomplish these three goals, and apply them to the problem of transferring between resonances in the Jupiter-Europa system.

For the first goal, we use the standard Melnikov method to find Keplerian periodic orbits which survive for small values of the mass parameter μ ; this perturbative analysis is followed by numerical continuation to compute the orbits for physically relevant μ values. This gives us a very large number of resonant periodic orbits. For 2), we implemented the parameterization method (Haro et al., 2016) to compute very high order polynomial approximations of the stable and unstable manifolds. Finally for 3) we develop an efficient bisection method which combines the previously computed polynomials with a Poincaré section to compute connections.

The tools developed were tested in the Jupiter-Europa system, with the calculations taking only a few minutes on a laptop for a given pair of resonances. We were able to find polynomial approximations of resonant orbit stable and unstable manifolds to degree 25 or even higher; these expansions resulted in a 1000x improvement in the domains of accuracy of the manifold representations as compared to just using linear approximations. The polynomials were then used to successfully compute several different resonance transitions, demonstrating the usefulness of these parameterizations to mission design.