Stellar Triples in PHOEBE

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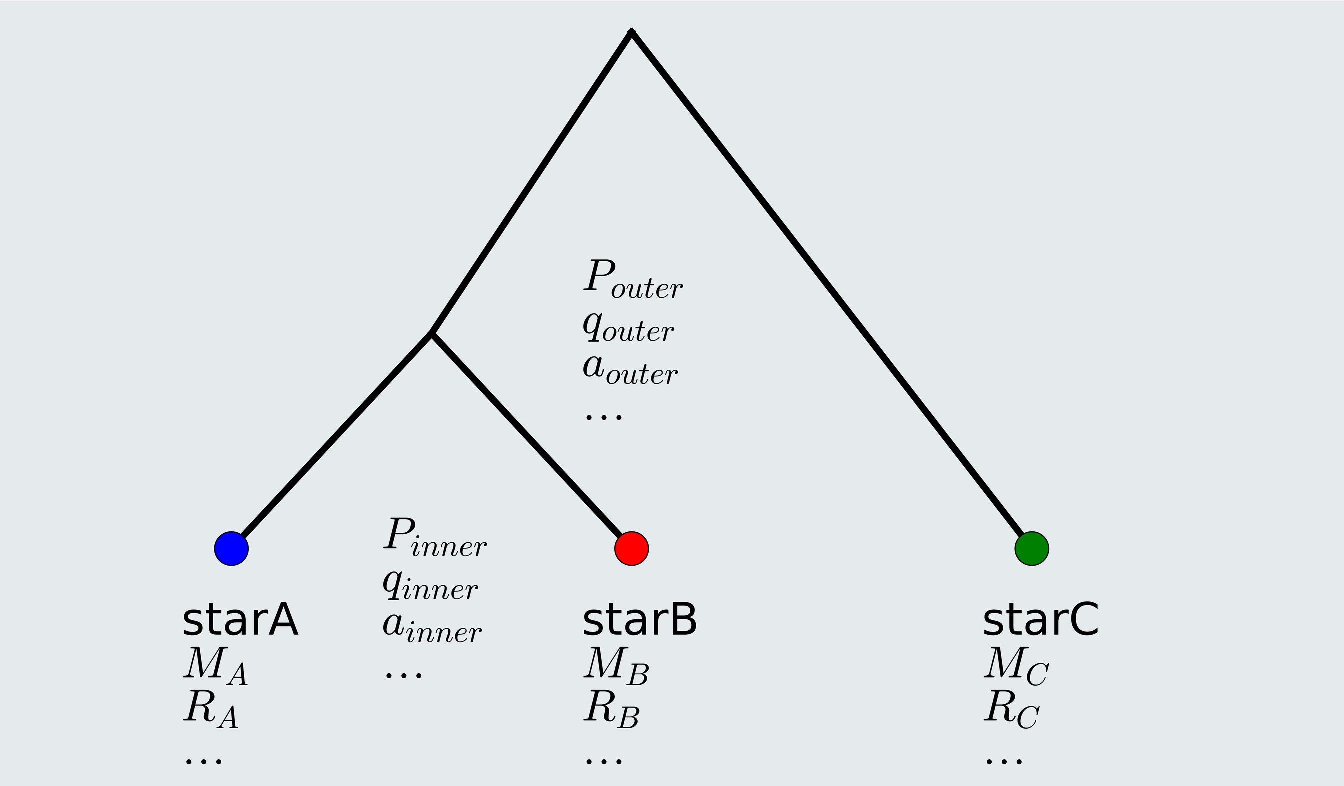
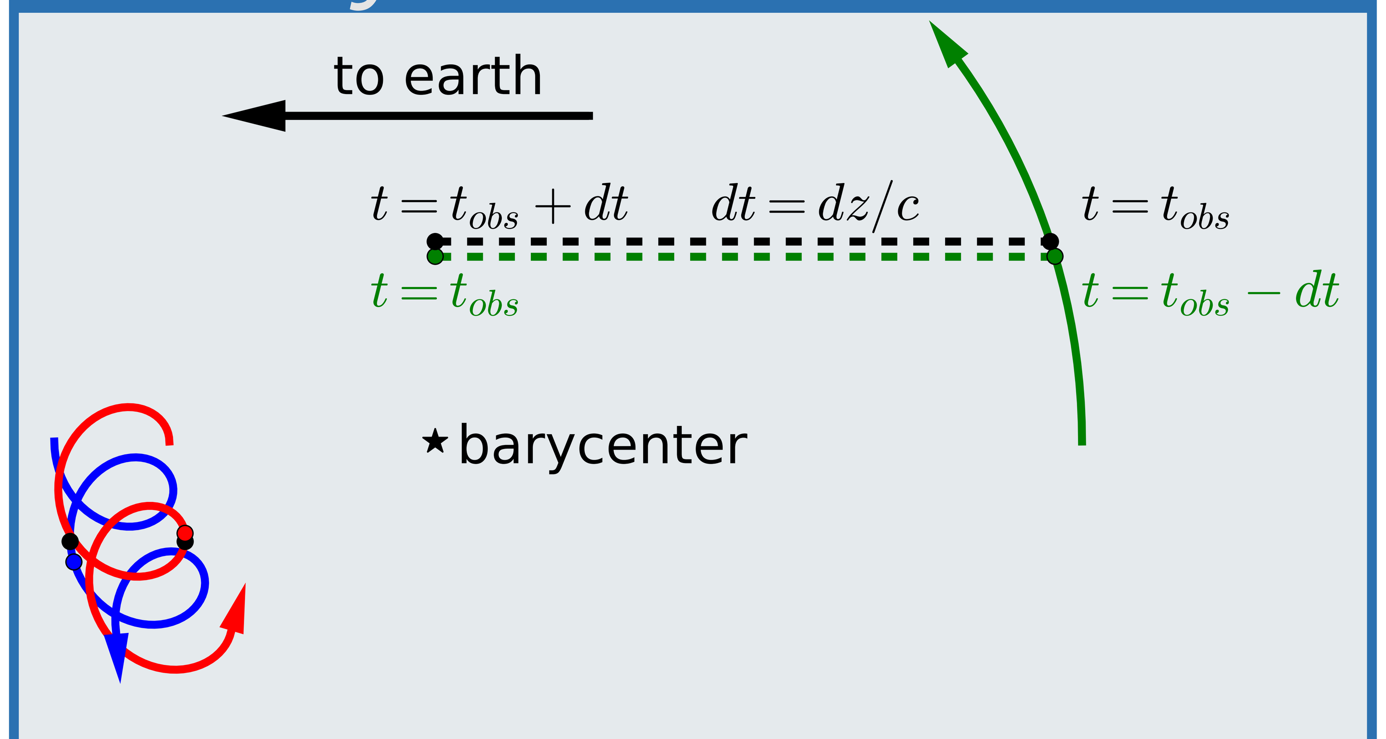
The number of known mutually-eclipsing stellar triple and multiple systems has increased greatly during the *Kepler* era. These systems provide significant opportunities to both determine fundamental stellar parameters of benchmark systems to unprecedented precision as well as to study the dynamical interaction and formation mechanisms of stellar and planetary systems. Modeling these systems to their full potential, however, has not been feasible until recently. Most existing available codes (eg. Carter et al. 2011, Orosz & Hauschildt 2000) are restricted to the two-body binary case and those that do provide N-body support for more components make sacrifices in precision by assuming no stellar surface distortion. We have completely redesigned and rewritten the PHOEBE binary modeling code to incorporate support for triple and higher-order systems while also robustly modeling data with Kepler precision.

Hierarchy



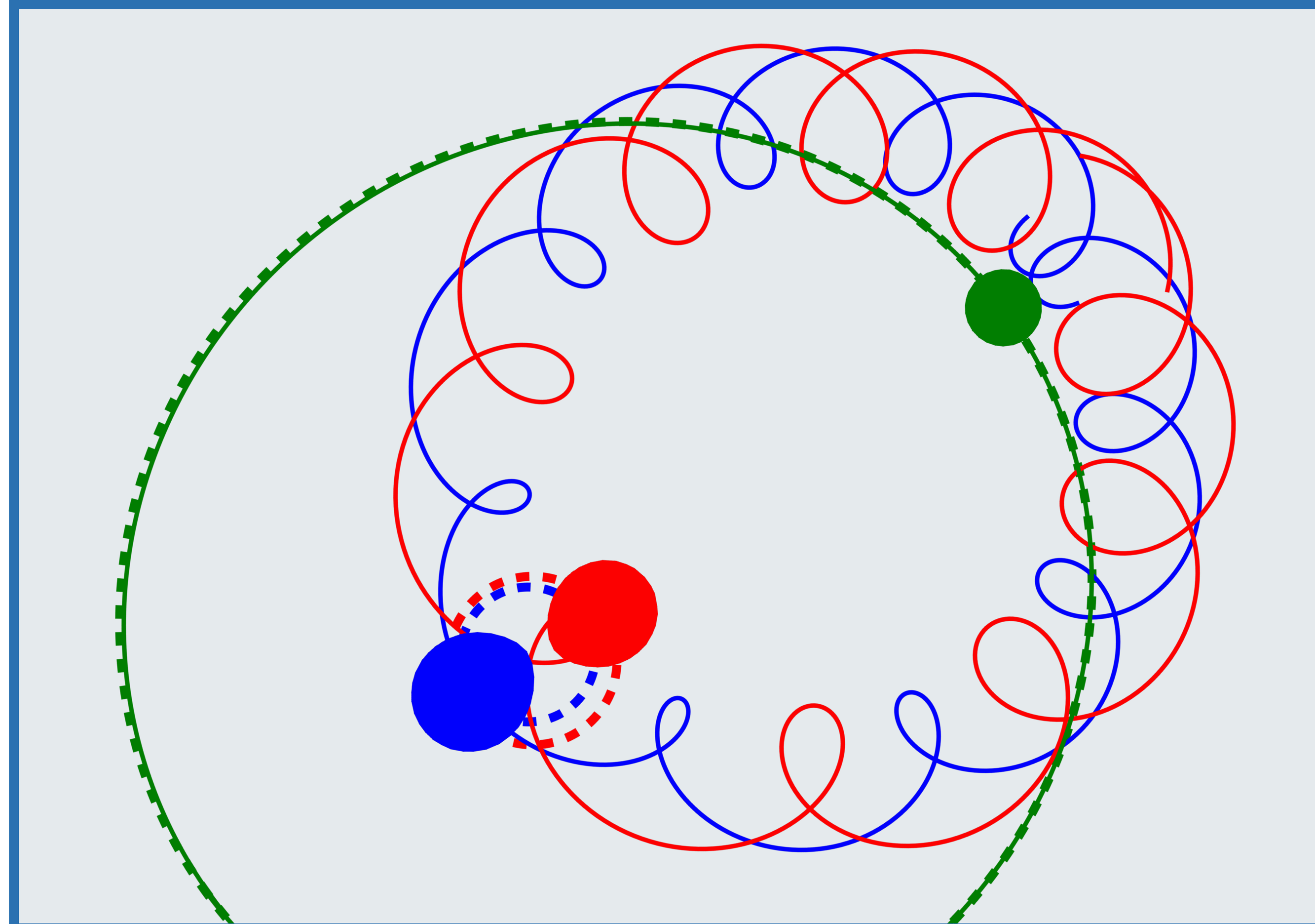
Orbits are defined in a nested hierarchy with Keplerian elements. Constraints allow for automatically deriving one of the 6 Keplerian elements: P_{inner}, q_{inner}, a_{inner}, P_{outer}, q_{outer}, a_{outer}.

Dynamics & LTTE



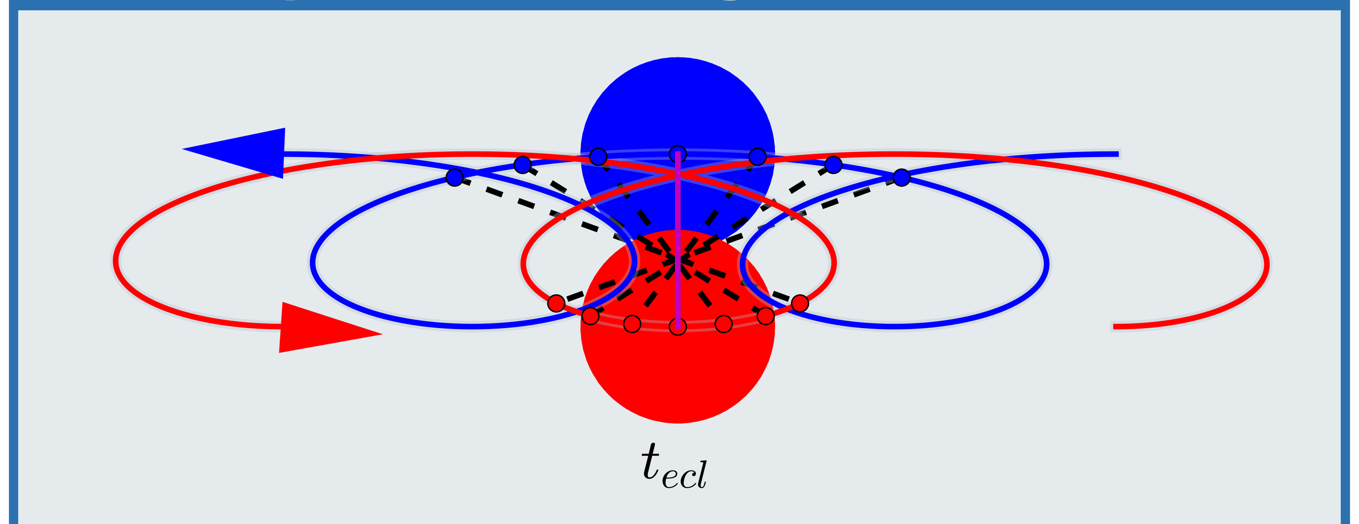
Each object is placed in orbit at each observed time using the rebound (Rein & Liu 2012) N-body integrator. These positions are then adjusted so that the light from each object reaches the barycenter of the system simultaneously.

Distortions



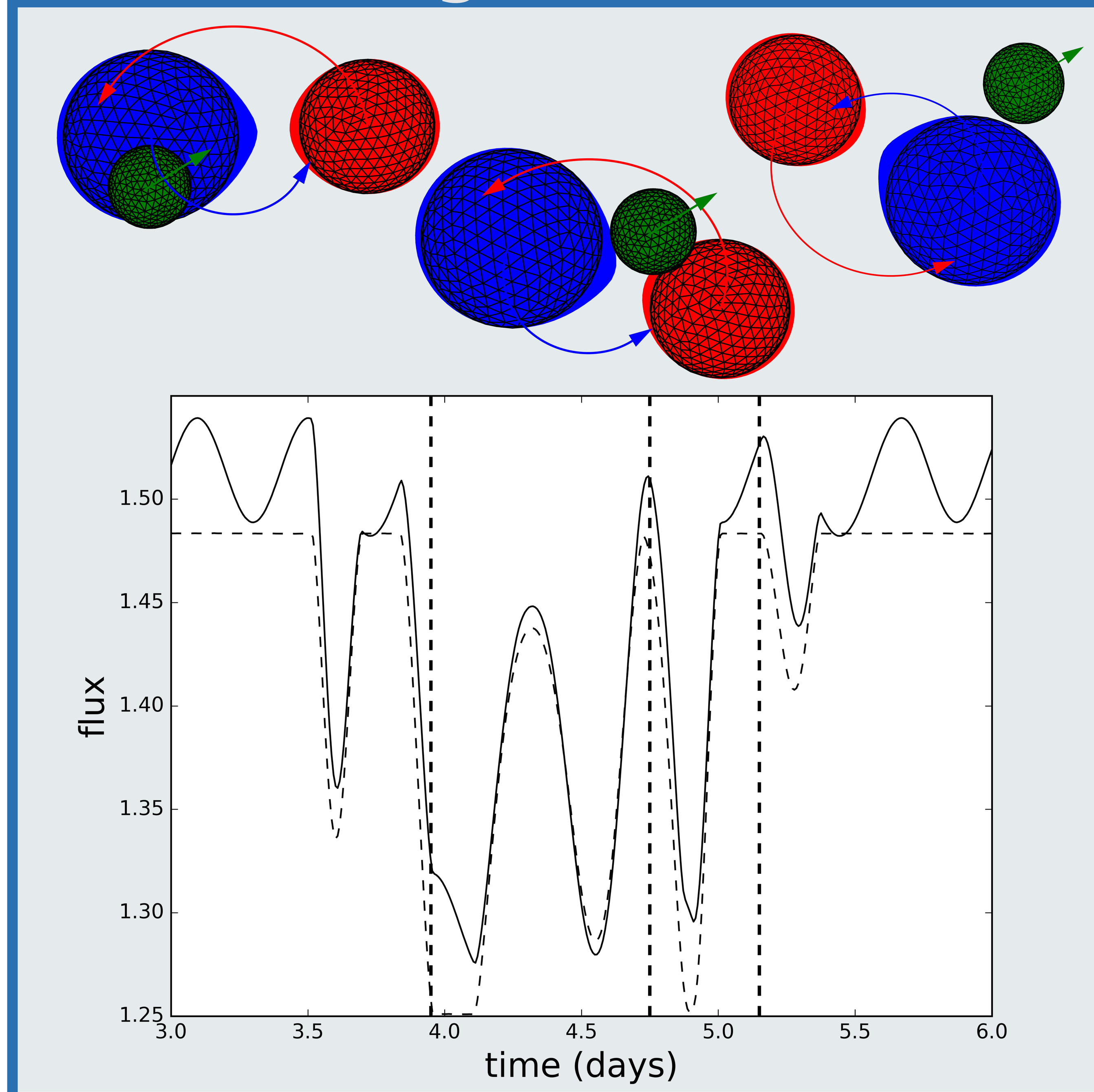
From the N-body positions and velocities, instantaneous keplerian orbits are determined (dashed) and used to update the roche surfaces by assuming volume conservation of each object.

Eclipse Timing Variations



Computed eclipse times are determined by minimizing the projected distance on the plane of the sky for any two stars. Determining and fitting eclipse times allows for modeling long-term effects without the computational expense of modeling the entire light curve.

Light Curves



The difference between rotating spheres (wireframes and dashed light curve) and roche stars (solid colors and solid light curve) can have a significant influence on the precise shape of the light curve. Whenever distortion AND dynamical effects can play a role, both of these effects need to be enabled for accurate results. The inclusion of these distortions is what sets PHOEBE apart from existing codes that handle triple stellar systems.

References
Carter, J. A., et al. 2011, Science, 331, 6017, 562-567
Orosz, J. A. & Hauschildt, P. H. 2000, A&A, 364, 265
Rein, H. & Liu, S. F. 2012, A&A, 537, A128

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PHOEBE is an open-source project
http://phoebe-project.org
http://github.com/phoebe-project