

ULTRA-HIGH PRECISION PHOTOMETRY OF OVERCONTACT BINARY STARS: FUNDAMENTAL PROPERTIES AND EVOLUTION

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This proposal focuses on the fundamental properties of overcontact binary stars -- short-period systems where the two main sequence components share a common envelope. Our understanding of formation, evolution and physical properties of overcontact binaries is incomplete, mostly due to the limited data accuracy. Kepler will alleviate this problem, allowing us not only to advance, but to essentially resolve the standing issues that have persisted in the field of close binaries for over 40 years. These are: 1) the formation of overcontact binaries. The two competing theories attribute the tightening of close binary orbits and subsequent coalescence to either a steady angular momentum loss due to tidal and rotational friction, or to interactions with the third body. Kepler's uninterrupted observations will establish the current angular momentum loss, which will enable us to turn back time and compute whether steady angular momentum loss could feasibly cause coalescence; 2) the dominant energy transport mechanism in overcontact binary envelopes. The current standing theory asserts that thermodynamic equilibrium is sustained by the so-called Thermal Relaxation Oscillation (TRO) cycle. In essence, one component overflows its Roche lobe, causing mass transfer on the other component. The transferred mass veils the component completely, blocking the flux, converting it to thermal energy and causing the increase in the radius of the veiled component. Once that component grows over its Roche lobe, the process is reversed. Lately, however, this model has been theoretically shaken by showing that the Coriolis force would cause veiling only in the equatorial regions of the star, thus enabling it to keep radiating energy through the polar regions. Kepler's photometric data accuracy will allow us to directly observe veiling: if only a band covers the star, there will be a discrete jump in its disk brightness at the band boundary, an effect routinely modeled in the field of eclipsing binaries. If such a jump is found, it will have proven that the TRO hypothesis cannot adequately describe the mechanism that sustains the thermodynamic equilibrium; 3) many overcontact binaries show evidence of geometric contact but not thermal contact. The data accuracy so far inhibited our ability to correlate the two, but with the promise that Kepler brings, physical parameters of overcontact binaries will be determined to a sufficient accuracy via modeling to formulate this correlation; 4) since most overcontact binaries show signs of chromospheric activity, we will be able to directly probe differential rotation and limb darkening of severely distorted stars; lastly, 5) we invested significant effort to reformulate the theoretical model backbone so that it withstands Kepler's data accuracy. Our model builds on the Roche constricted three body hypothesis, where stars are considered point sources, surrounded by a massless envelope. This approximation proved adequate for ground-based observations, but Kepler will put the extent of applicability of this model to the test. Any deviation will have strong implications on the eclipsing binary modeling in general. Our study will be based on a carefully selected sample of 50 overcontact binary stars in the Kepler field of different variation amplitudes and orbital periods. Two of those exhibit total eclipses, making them ideal astrophysical laboratories for the focused, in-depth study. For these we propose short cadence observations (half a year each, occupying a single short cadence channel overall), and for the remaining program stars we propose the long cadence mode. Analyzing this sample will not only answer the listed questions, it will also yield physical and geometrical properties of these stars of unprecedented accuracy in a uniform way. Our research team has extensive experience (both theoretical and observational) in eclipsing binary stars and we feel well positioned to conduct this research successfully.