Dynamical Tides in Eccentric Binaries and Tidally-Excited Stellar Pulsations in KEPLER KOI-54

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Recent observation of the tidally-excited stellar oscillations in the main-sequence binary KOI-54 by the KEPLER satellite provides a unique opportunity for studying dynamical tides in eccentric binary systems. We develop a general theory of tidal excitation of oscillation modes of rotating binary stars, and apply our theory to tidally excited gravity modes (g-modes) in KOI-54. The strongest observed oscillations, which occur at 90 and 91 times the orbital frequency, are likely due to prograde m=2 modes (relative to the stellar spin axis) locked in resonance with the orbit. The remaining flux oscillations with frequencies that are integer multiples of the orbital frequency are likely due to nearly resonant m=0 g-modes; such axisymmetric modes generate larger flux variations compared to the m=2 modes, assuming that the spin inclination angle of the star is comparable to the orbital inclination angle. We examine the process of resonance mode locking under the combined effects of dynamical tides on the stellar spin and orbit and the intrinsic stellar spindown. We show that KOI-54 can naturally evolve into a state in which at least one m=2 mode is locked in resonance with the orbital frequency. Our analysis provides an explanation for the fact that only oscillations with frequencies less than 90-100 times the orbital frequency are observed. We have also found evidence from the published KEPLER result that three-mode nonlinear coupling occurs in the KOI-54 system. We suggest that such nonlinear mode coupling may explain the observed oscillations that are not harmonics of the orbital frequency.

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