Impact of Dynamical Tides on the Light Curve of the Hot White Dwarf Binary System KOI-964

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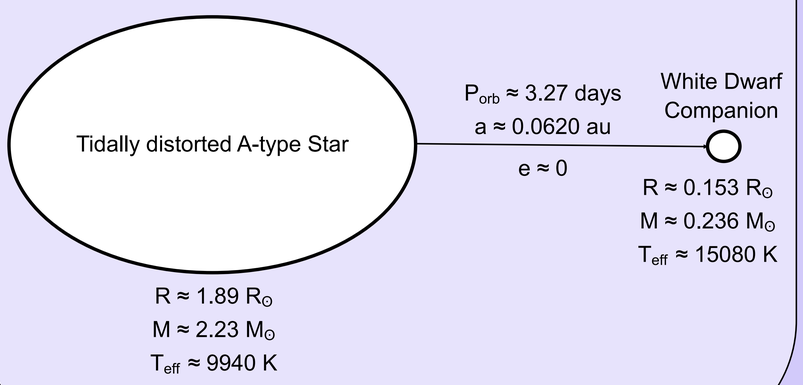
Introduction:

The *Kepler* binary system KOI-964 consists of a hot white dwarf and an A-type star in an eclipsing 3.3 day circular orbit. The white dwarf raises a strong tide in the A-type star which distorts its shape and induces significant flux perturbations. Wong et al. (2018) analyze long cadence *Kepler* photometry, and with it successfully explain several features of the observed light curve. However, their model for the tide-induced flux perturbations underestimates the observed amplitude by 45%. We study whether this discrepancy is due to their neglect of internal gravity waves (g-modes) which can be resonantly excited within the A-type star by the tide, i.e. the dynamical tide. We use the stellar evolution code *MESA* and the stellar oscillation code *GYRE-tides* to examine the effects of g-mode excitation on the observed light curve.

Methods:

- We first create a stellar model of the A-type host using *MESA* that matches the observed mass and temperature of KOI-964.



- We then read this model into *GYRE-tides*, which is used to calculate numerous useful quantities throughout the star, including the mode frequencies.

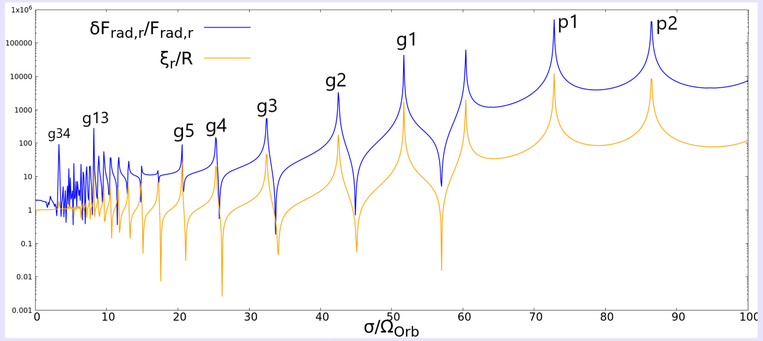


Fig. 1: Radial tidal displacement ξ_r and flux perturbation $\delta F_{rad}/F_{rad}$ versus frequency in units of orbital frequency, σ/Ω_{Orb} corresponding to low order gravity waves (g-modes) and sound waves (p-modes).

- Plots like Fig. 1 tell us how the observed flux perturbation depends on the orbital frequency of the system, i.e., whether the tide leads to a flux enhancement.
- KOI-964 is on a near-circular orbit of ~3.27 days and thus only modes associated with $\sigma/\Omega_{Orb} = 2$ will be excited in the host star.

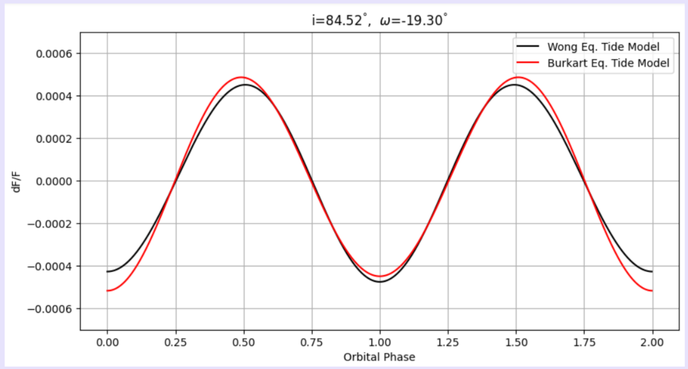


Fig. 2: Equilibrium tide flux perturbation versus orbital phase. The two curves show the models of Burkart et al. (2012) and Wong et al. (2019).

- Fig. 2 compares two models of the equilibrium tide, which describes the static tidal response of a star to the gravitational potential of its companion. The models are in good agreement, with small differences due to how limb and gravity darkening are treated.

Results:

- The flux perturbations are sensitive to the details of the stellar model and therefore uncertainties in the measured stellar parameters. We therefore create an array of models that tell us the likelihood of seeing a particular flux perturbation.

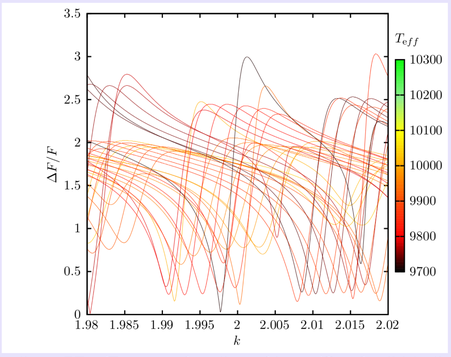


Fig. 3: Flux perturbations $\delta F_{rad}/F_{rad}$ as a function of $k = \sigma/\Omega_{Orb}$ for thirty-three distinct models consistent with the star's observed T_{eff}.

- Fig. 3 shows that a range of flux perturbations are possible depending on the star's true parameters.
- We are constructing a large set of stellar models in order to get a probability distribution of the flux perturbations. This will tell us the likelihood that the 45% flux underestimate found by Wong et al. is due to the neglect of g-modes in their tidal model.

References:

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