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Tidal forces and stability of circular and near-circular orbits of massive close-in planets: the CoRoT example

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Abstract

The ensemble of CoRoT planets is studied with regard to tidal interactions and orbital decay. Four simple principles are formulated for a first order estimate of orbital stability under tidal forces: i) present orbit within the virtual synchronous orbit with regard to stellar rotation, ii) the Doodson constant, iii) the property factor and iv) the critical orbit radius depending on remaining stellar life time and the dissipation Q_*/k_{2*}. Tidal forces are driving the planetary rotation synchronous with the orbital revolution within a few hundred million years if the planetary orbit is within 0.1 AU. From the 22 studied CoRoT planets, 15 are massive close-in hot Jupiters. Three of them are around G-stars and another three are around F-stars within 0.033 AU and 0.044 AU, respectively. Those will reach the Roche zone of their stars within the remaining stellar life time for $Q_*/k_{2*} \leq 10^7$. Scenarios of extremely small Q_*/k_{2*} are considered unrealistic because the planets would migrate into the stellar Roche zones in extremely short time scales and would spin up strongly the stellar rotation. A special class of fast rotating old sun-like stars is, to our knowledge, not observed. Tidal forces may drive the stellar rotation and the planetary orbit into double synchronous rotation. This state may eventually be achieved but is considered as unstable. The slow-down of the stellar rotation by magnetic braking (strong with G-stars, weak with F-stars) will drive the synchronous orbit outward and out of the double synchronous state which leaves the planetary orbit within the synchronous orbit.