ESTIMATION OF HOT JUPITER TIDAL INFALL RATE IN THE GALAXY

Abstract: Among various mechanisms, tidal interaction plays a critical role in its impact on the dynamics of close-in planetary systems. This is especially true for systems with hot Jupiter, as tidal dissipation provides rapid migration of the most massive planets leading to their engulfment. We study the orbital evolution of hot Jupiters around solar-mass pre-main sequence (PMS) and main sequence (MS) stars following the tidal prescriptions from Barker (2020), allowing to investigate the dissipation of equilibrium tide, inertial waves, and gravity waves over the wide parameter space. Based on our results, we simulate the hot Jupiter population and derive the statistics of planetary infalls within the Galactic thin disk.

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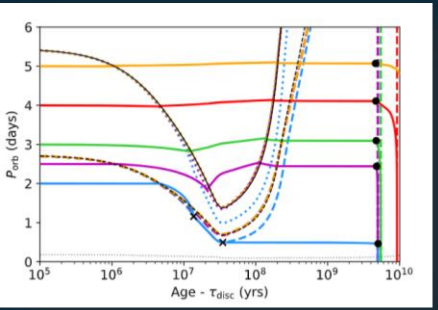
Key features of secular evolution of hot Jupiters:

1. gravity waves substantially increase the infall probability;
2. gravity waves dominate in systems with a low stellar initial spin;
3. inertial waves dominate in systems with a high stellar initial spin;
4. metal-rich stars are favored in terms of tidal migration under the dissipation of gravity waves;
5. generally, fast rotators engulf their planets earlier than slow rotators;
6. MS stars with convective cores do not exhibit dissipation of gravity waves;
7. for stars with radiative core, the impact of gravity waves sharply decreases with decreasing stellar mass.

We explore the impact of stellar mass, initial rotation and metallicity on the migration of hot Jupiter with a given mass and initial separation. The orbital tracks are eventually converted into the infall diagram.

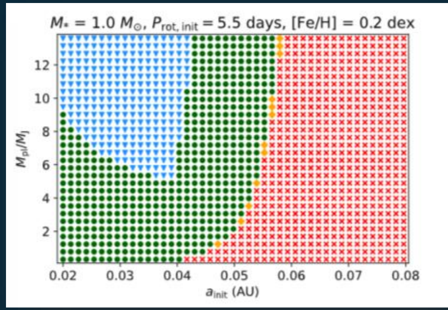
Secular evolution



$(M_{pl} = 3M_J, M_* = 1.0M_\odot, P_{rot,\,init} = 5.5\text{ days}, [Fe/H] = 0.2\text{ dex})$

Black solid and dashed lines: corotation radius and inertial wave excitation limit of an isolated star. Colored solid lines: planetary orbital tracks. Black circles: starting time of gravity wave dissipation.

Infall diagram



Red crosses – stable systems. Orange diamonds – intermediate outcome. Green circles – infalls due to gravity waves. Blue triangles – infalls due to equilibrium tide.

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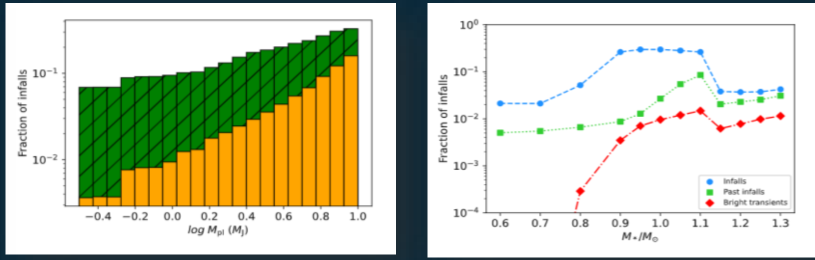
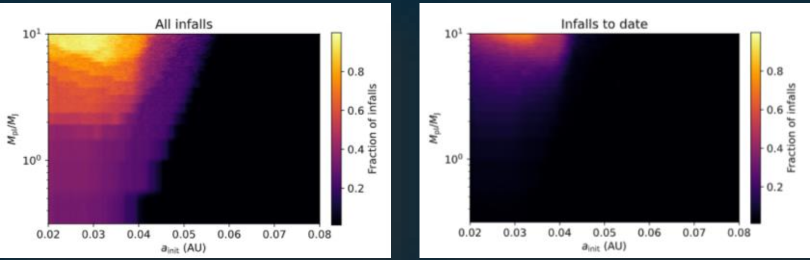


Left panel: engulfment ratio as a function of planetary mass. Right panel: engulfment ratio as a function of stellar mass.



Engulfment ratio distribution in the mass – initial separation diagram;
Left panel: total number of infalls. Right panel: infalls to date.

Main results:

1. 11 – 21% of the initial hot Jupiter population merge with the host star within the MS lifetime (or 14 Gyr for stars with t_{MS} < 14 Gyr);
2. 1.5 – 3.0% of the initial hot Jupiter population is already engulfed;
3. the present-day infall rate in the Galaxy is 340 – 650 events per million years;
4. 2.4 – 3.7 decaying systems can be discovered within the first decade of the observation at PLATO.