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By Jove, what a crowd!

On the Prevalence of Hot Jupiters in M67

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TL;DR

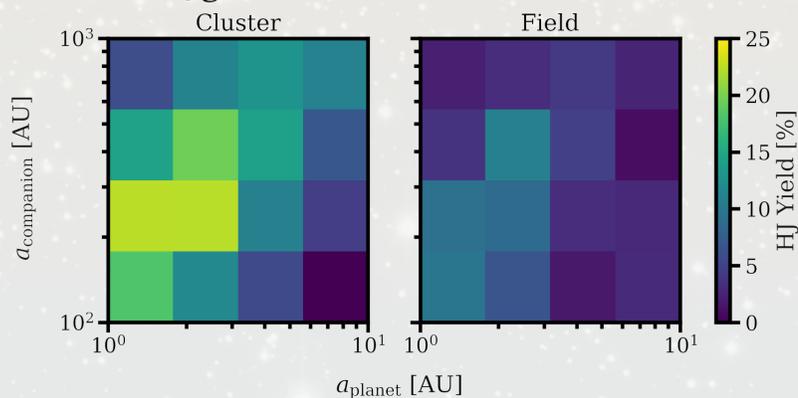
The elevated occurrence rate of hot Jupiters in the open cluster M67 may be explained by more efficient formation due to dynamical interactions with other cluster members provided that high-eccentricity migration in stellar binaries is the dominant formation channel.

Background

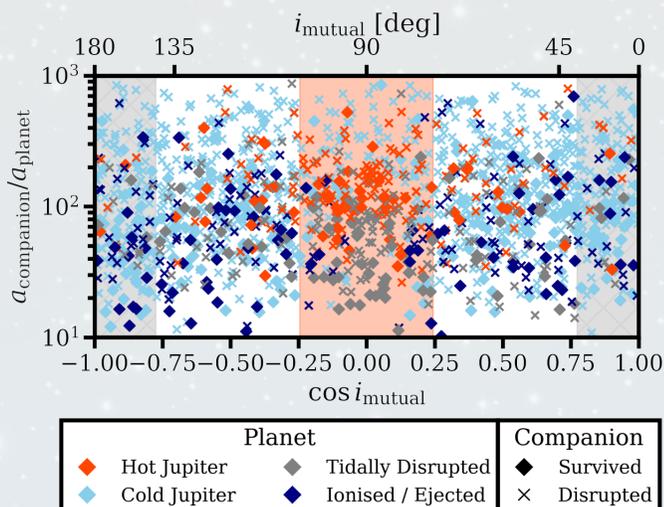
- **Hot Jupiters (HJs)** are short-period ($P < 10$ d) giant planets likely formed beyond the snowline and delivered inward through disc migration or **high-eccentricity tidal migration (HEM)**.
- Around 1% of FGK stars in the Galactic field host hot Jupiters, but in the **open cluster M67** their occurrence rate appears to be elevated up to 5.4% based on radial velocity surveys (Brucalassi et al. 2016, Thomas et al. 2024).
- We investigate whether this excess could be due to **close encounters** with other cluster members triggering dynamical instabilities (e.g. von Zeipel-Kozai-Lidov oscillations, planet-planet scattering) which enable HEM.

Results

- We find hot Jupiter formation through direct flyby excitation in single- and two-planet systems to be **inefficient** in a relatively low-density ($n_* \sim 100$ pc⁻³) open cluster environment, consistent with previous work.
- However, in systems with a stellar companion, the hot Jupiter formation rate is **more than doubled** (4.9% \rightarrow 12.5%) and the tidal disruption rate **tripled** (4.2% \rightarrow 13.5%) in the cluster environment compared to the control sample.
- The enhancement is not uniform across the parameter space but instead points to **initial configurations** for which HJ formation is favoured:



- The main driver of the enhancement is the diffusion of otherwise inactive systems into the **mutual inclination window** in which strong eccentricity excitation through the von Zeipel-Kozai-Lidov mechanism is possible:

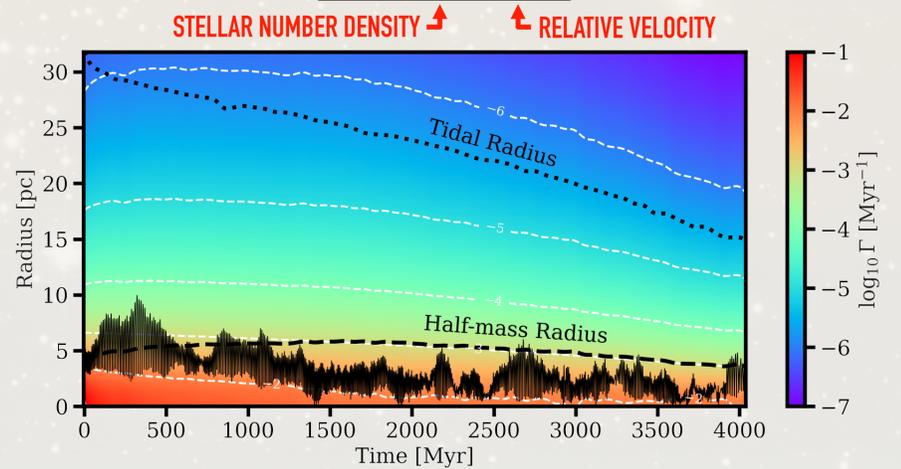


Methods

- We extend a **hybrid approach** developed by Wirth et al. 2025 to model the secular and tidal evolution of planetary systems under the influence of **stellar flybys** using a combination of analytic and numerical methods.
- The cluster is modelled as an **evolving Plummer sphere** calibrated to the Hurley et al. (2005) N-body model of M67.
- We treat the host star ($1 M_{\odot}$) as a test particle evolving under the influence of gravity, dynamical friction, and diffusive kicks, with the instantaneous **encounter rate** given by the mean free path approximation:

$$\Gamma \sim n_* \Sigma v_{\infty}$$

ENCOUNTER CROSS-SECTION



- Our simulations consist of 2,000 realisations each of three different **planetary system configurations**:

- Single Planet ($1 M_J$, 1–10 AU)
- Planet (") + Outer Planetary Companion ($1\text{--}13 M_J$, 1–100 AU)
- Planet (") + Outer Stellar Companion ($0.1\text{--}1 M_{\odot}$, 100–1,000 AU)

- We evolve each system for 4 Gyr in the cluster and compare the outcome probabilities to a **control run without stellar flybys**.

Discussion

- We estimate the **occurrence rate** of hot Jupiters formed in wide binaries as:

~ 0.2 (Hirsch et al. 2021)

OUR MODEL

$$\mathcal{F}_{\text{HJ}} = f_{\text{GP}} \times f_{\text{bin}} \times (f_{\text{HJ}} + f_{\text{TD}} \times f_{\text{surv}})$$

~ 0.6 (Hurley et al. 2005) ~ 0.6 (Weldon et al. 2025)

- Adopting observationally and theoretically motivated estimates, our results are **consistent with both the field ($\sim 0.9\%$) and M67 ($\sim 2.5\%$) rates** within uncertainties if binary-driven HEM is the dominant HJ formation channel.

- A $\sim 50\%$ enhancement in HJ occurrence among cluster escapers compared to isolated systems suggests **dynamical processing in dissolved clusters** may contribute a non-negligible fraction of the field hot Jupiter population.

References