Understanding the Planetary Formation and Evolution in Star Clusters(UPiC)-I: Evidence of Hot Giant Exoplanets Formation Timescales

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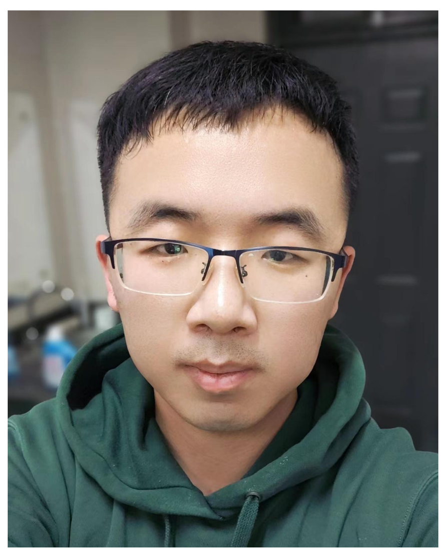

Abstract

Planets in young star clusters could shed light on planet formation and evolution since star clusters can provide accurate age estimation. The UPiC project aims to find observational evidence and interpret how planet form and evolve in cluster environments. In this work, we cross-match the stellar catalogs of new OCs and comoving groups with confirmed planets and candidates. We carefully remove false positives and obtain the biggest catalog of planets in star clusters up to now, which consists of 73 confirmed planets and 84 candidates. After age validation, we obtain the radius—age diagram of these planets/candidates. We find the proportion of Hot Jupiters(HJ) increses around 100 Myr which may be attributed to high-e migration in star clusters. Different from HJs in star clusters, the proportion of HJs around fields has a peak around 2 Gyr. The different HJ formation timescale implies the influence of stellar environments (density). Besides, we find that the hot-Neptune desert occurs around 100 Myr which may be sculpted by photoevaporation and high-e migration.

1. Motivation

Only ~30 planets in clusters → **More clusters more cluster members** → **More stars in clusters, more planets in clusters** → **Understanding the Planetary formation and in Clusters(UPiC)**

2. Catalog of Planets/Candidates in Star Clusters

- **The biggest catalog of planets(73)/candidates(84) in star clusters.**
- Age validation—valide 70 planets/candidates with relatively robust age estimations and exclude 8 systems without convincing age
- Sample cut, i.e. $2R_\oplus<R_p<2.5R_J$, P<20 days, RUWE<1.4 and $\sigma_{Rp}/Rp<0.5$

3. Results

3.1 Planet Radius—Age Diagram

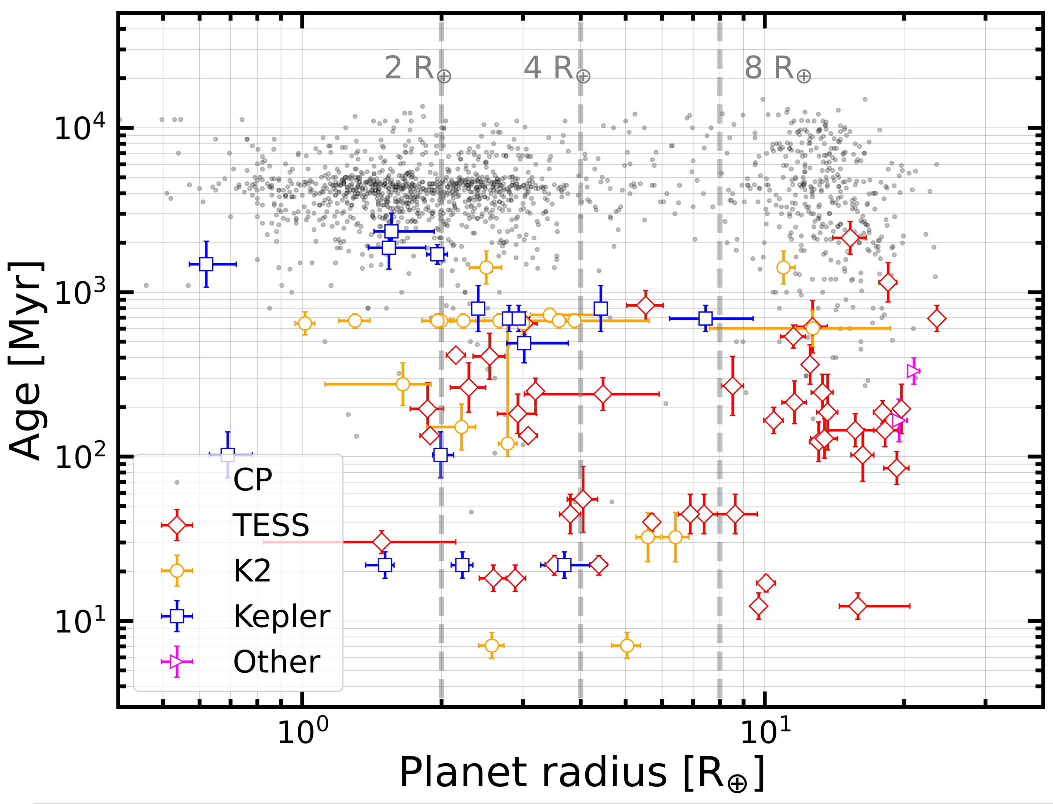

Figure 1. The planetary radius - age distribution of 37 planets and 44 candidates in star clusters. Red, yellow, blue, and purple symbols are planets/planet candidates detected by different missions

Planets of different sizes:

- Sub-Neptunes: $2—4\ R_\oplus$
- Sub-Jupiters: $4—8\ R_\oplus$
- Jovian planets: $8R_\oplus—2.5\ R_J$

3.2 The Evolution of Planet Radius

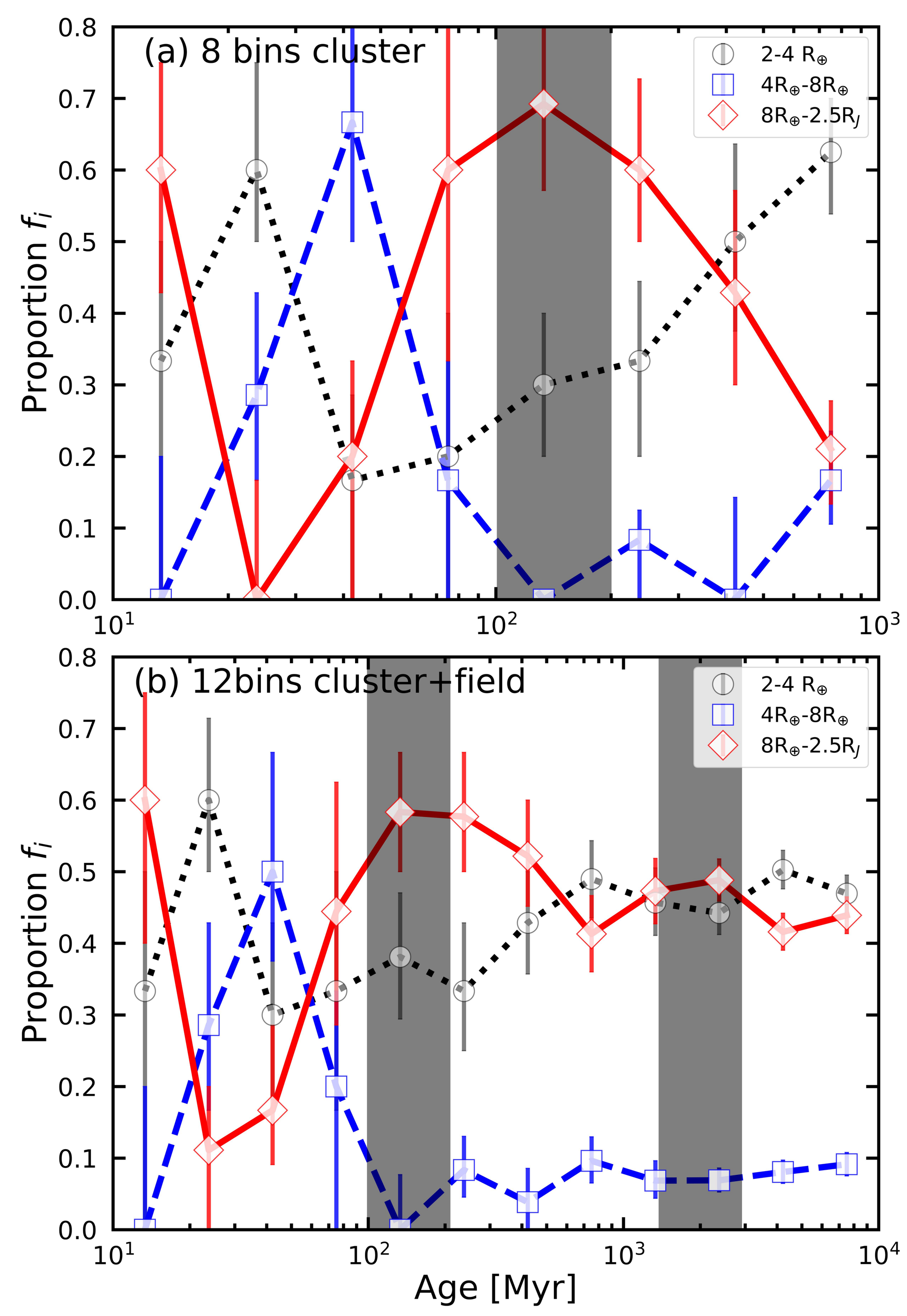

Figure 2. The time-dependent relation of the proportions of planets different sizes in star clusters [panel (a)] or both in star clusters and around field stars(>1Gyr) [panel (b)].

The proportion of planets with different sizes and ages, f_i

$$f_i = \frac{N_i}{N_{SubN} + N_{SubJ} + N_J}$$

- f_J increases around **100 Myr.** A tiny bump of f_J is around **2 Gyr**.
- f_{SubJ} declines rapidly around **100 Myr**, then remains at a low value.

4. Discussions

4.1 Flyby-induced High-e Migration in Star Clusters

Model: a Sun-Jupiter system + an outer companion + flyby

Flyby τ_{flyby} **~ 100 Myr** → **ZKL** τ_{ZKL} **< 1 Myr**; **Tidal circularization** τ_{tidal} **< 100 Myr** → **HJ formation** τ_{HJC} **< 200 Myr**

The increase of the proportion of HJs could be attributed to flyby-induced high-e migration in star clusters.

4.2 High-e Migration around Field Star beyond 1 Gyr

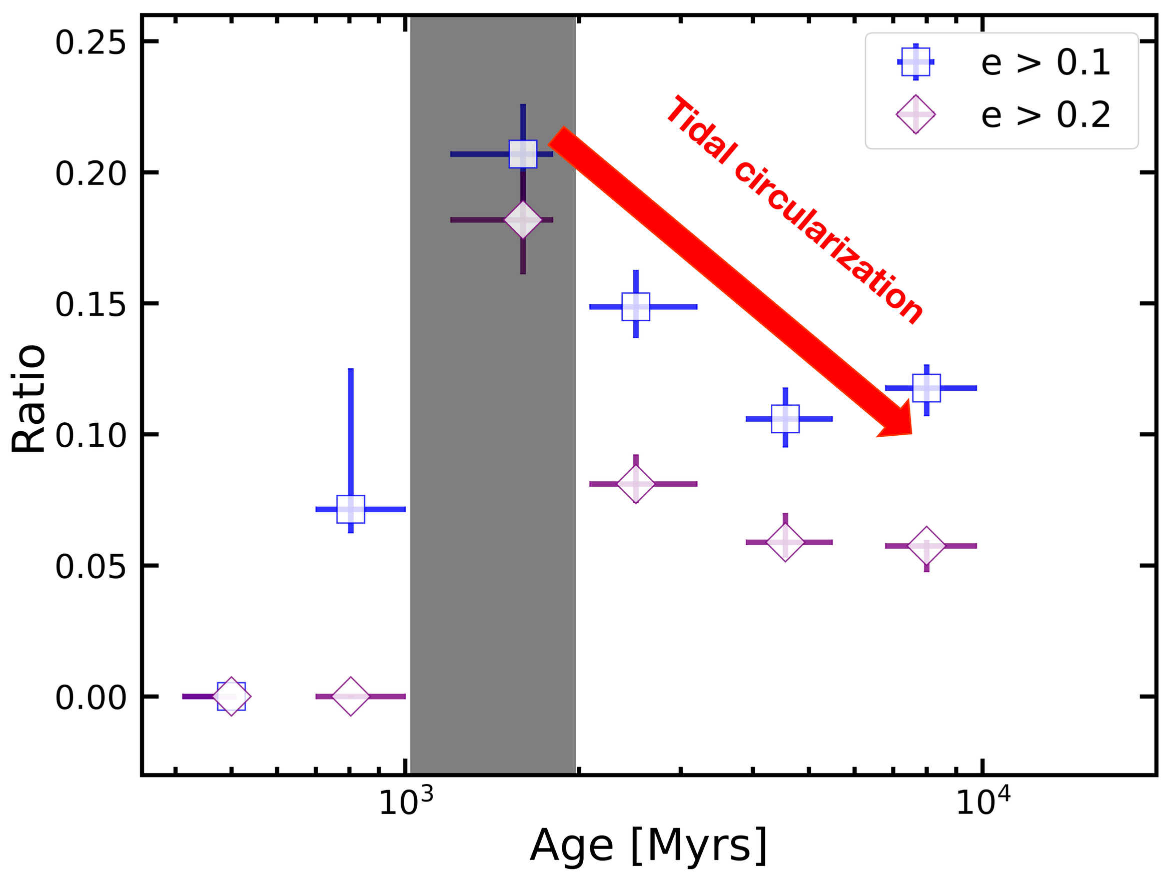

Figure 3. The ratio of high-eccentricity HJs changing with age. The blue and purple dots are the ratio of HJs with e>0.1 and e>0.2 changing with age, respectively.

Why Different HJs' formation timecales? Stellar density

4.3 Hot-Neptune Desert occurs around 100 Myr

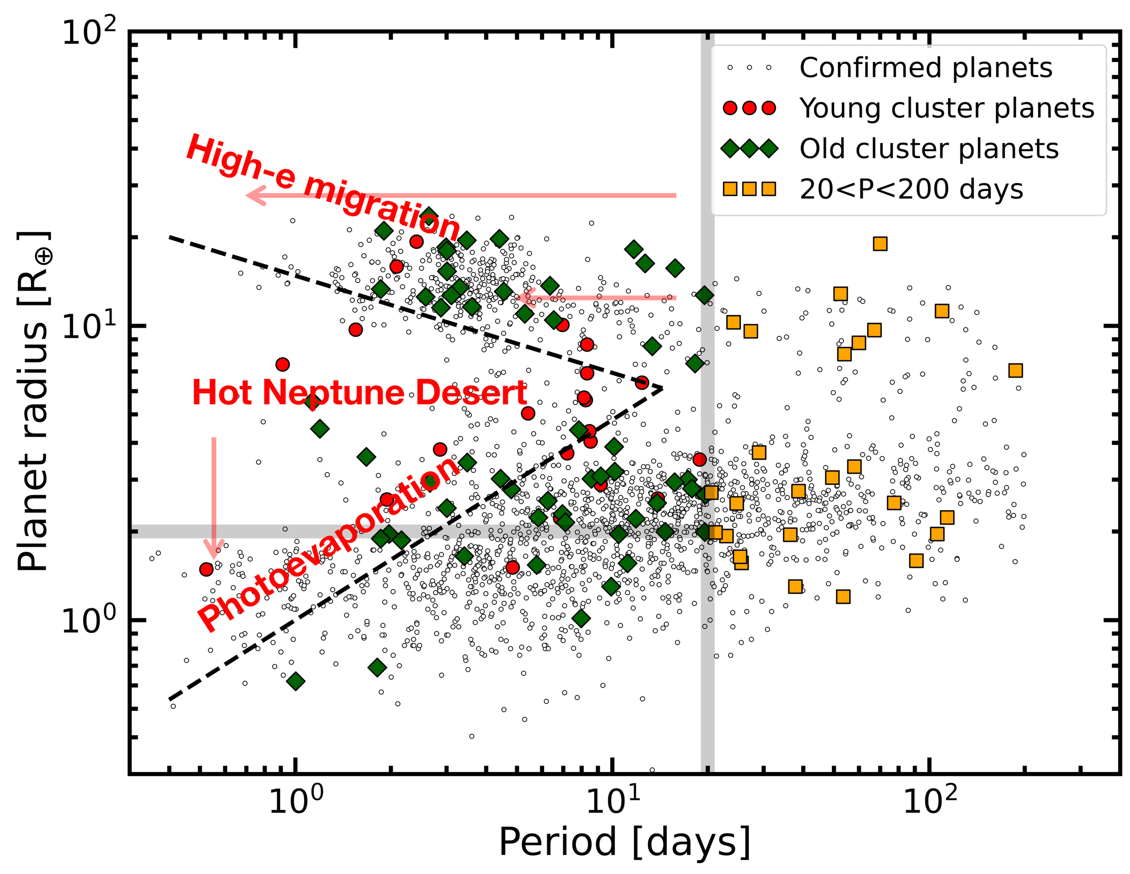

Figure 4. The scatter plot of planets in planets radius-period plane. Red: P<20 days, age<100 Myr. Green: P<20 days, age>100 Myr. Orange: 20<P<200 days.

Photoevaporation High-e migration

5. Conclusion

- We get the biggest catalog of 157 planets/candidates in star clusters.
- We find the increase of the proportion of HJs (f_J) around 100 Myr (High-e)
- We find the small bump of f_J around 2 Gyr, nearly ten times of τ_{HJC}, which implies the contribution of cluster enviroments to HJ formation.
- We find that a combination of photoevaporation and high-e migration may sculpt the Hot-Neptune desert around 100 Myr of planets in clusters.