FORMING ROCKY EXOPLANETS AROUND K-DWARF STARS[1]

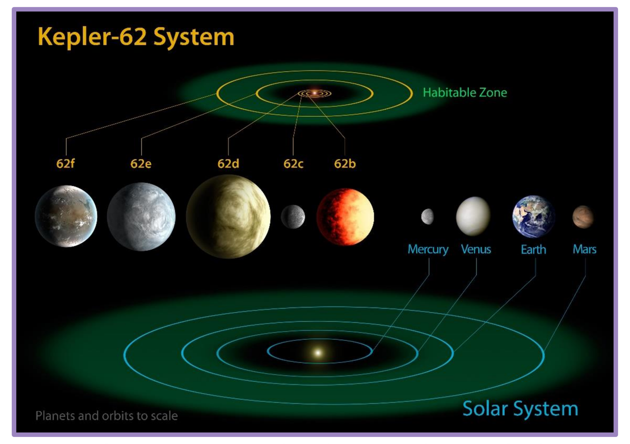
P. Hatalova[1], R. Brasser[1,2], E. Mamonova[1] and S. C. Werner[1]

[1]Centre for Planetary Habitability (PHAB), University of Oslo, Oslo, Norway
[2]HUN-REN CSFK; MTA Centre of Excellence, Budapest, Hungary

Petra Hatalova
petra.hatalova@geo.uio.no

Summary

- By employing N-body simulations of planet formation running on GPUs, the study reproduced the currently known population of close-in super-Earths observed around K-dwarf stars and their system characteristics.
- Such studies are essential for improving the understanding of the processes of planet formation.



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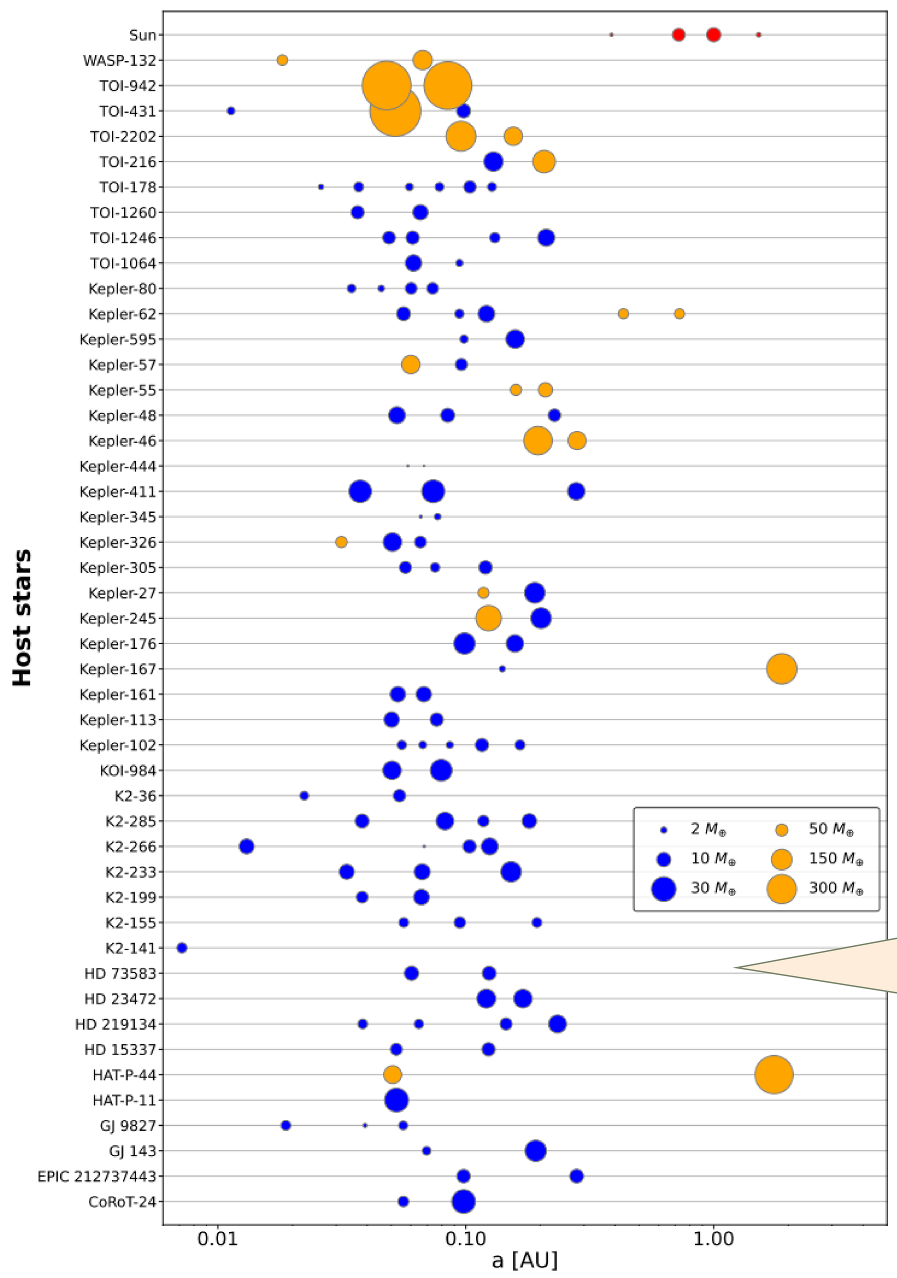
A) Introduction

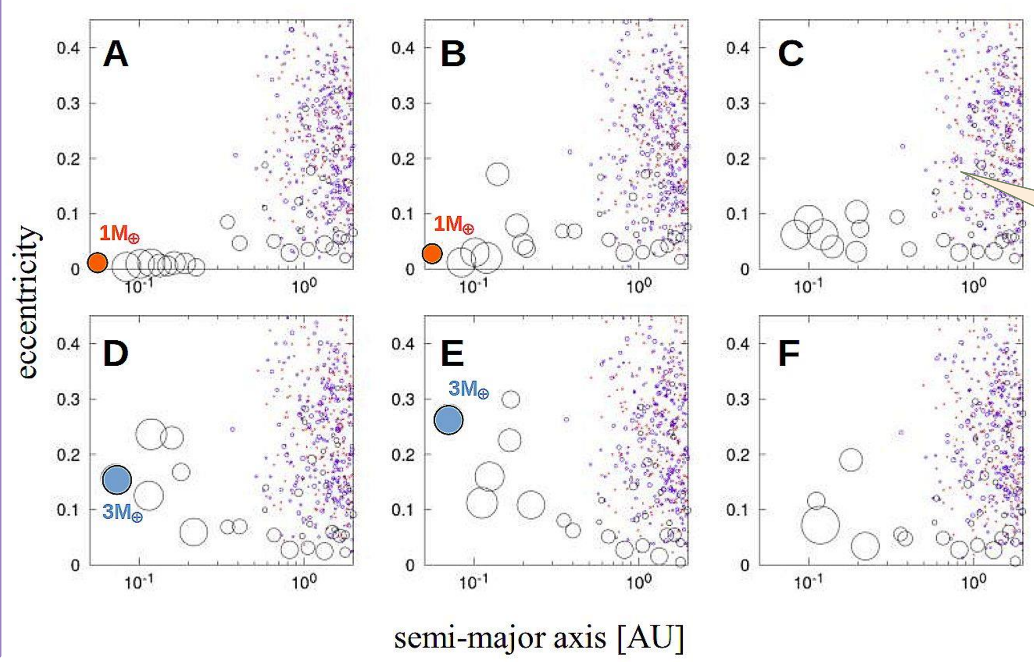


- New space telescopes aim to detect and study thousands of exoplanets, especially terrestrial planets around main-sequence stars.
- How multiple close-in super-Earths form around smaller stars is still an open issue.
- Several recent modeling studies have focused on planet formation around M dwarfs (0.08 to 0.6 solar masses).
- So far no studies have specifically targeted K-dwarf stars (0.6 to 0.9 solar masses), which are of particular interest in the search for extraterrestrial life.

Observed population around K dwarfs; stars slightly smaller and colder than our Sun. Compact multi-planet systems of mostly small, dense planets with short periods. Giant planets are not common.

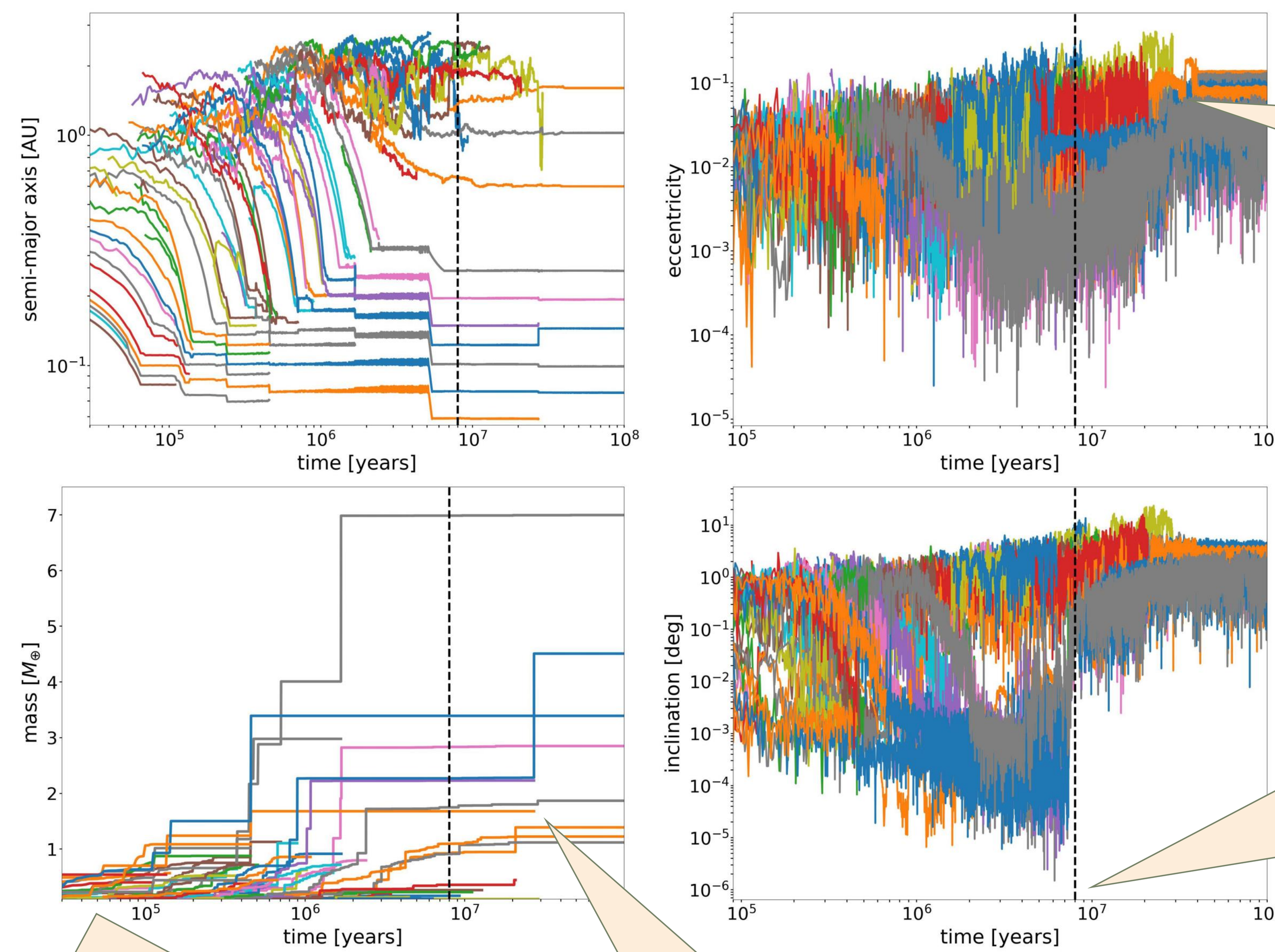
B) Methods

- We performed 48 high-resolution N-body simulations of planet formation via planetesimal accretion using the GENGA software[2,3] running on GPUs to simulate up to 100 Myr of evolution.
- We varied the initial protoplanetary disk mass and the solid and gas surface density profiles.
- Each simulation began with 12 000 bodies with radii of between 200 and 2000 km around two different stars with 0.6 and 0.8 solar masses.



Snapshots from one of the sims showing a dynamical instability at ~8.6 Myr. A resonant chain of planets located close to the star gets disrupted by another planet that migrates too close. It results in 2 planets falling onto the star.

C) Dynamical evolution - 100 Myr



Each color represents an individual object with > 0.1 M_{Earth}.

Most gas dissipates within ~8 Myr. Planet migration, and eccentricity and inclination damping cease.

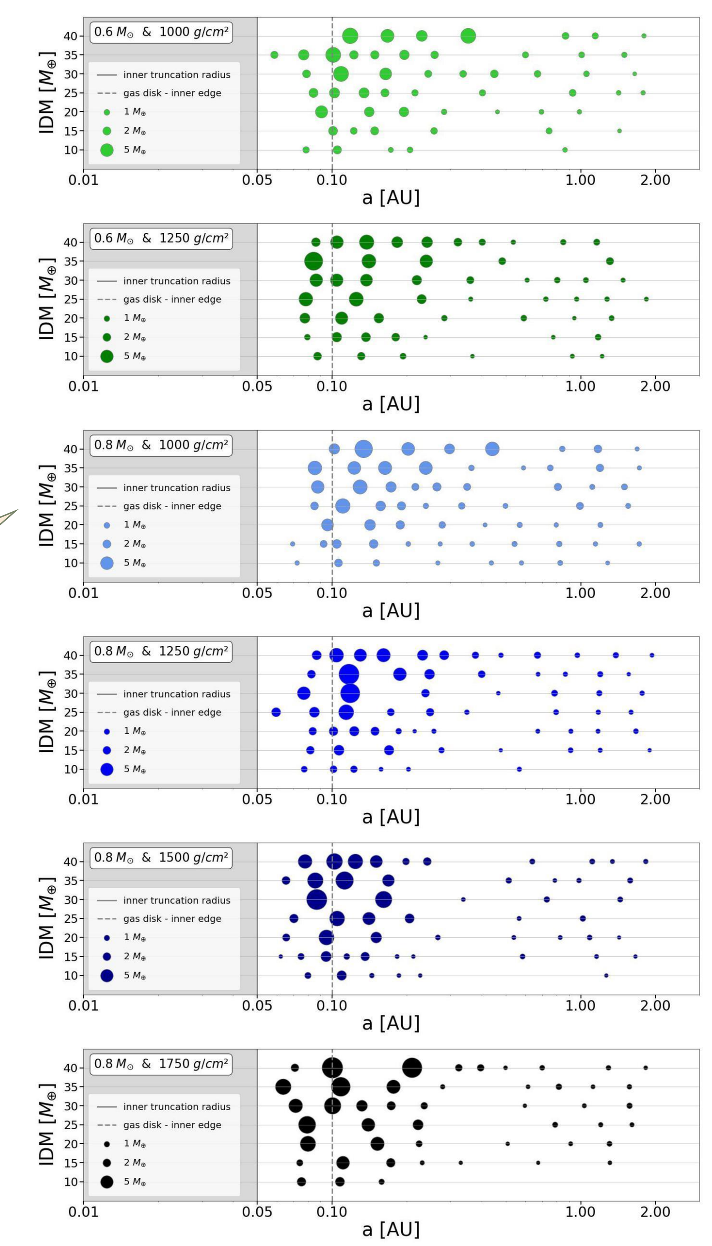
Earth-mass planets form quickly, within a few Myr, mostly before the gas disk dispersal.

Dynamical instabilities occurred at ~21 and 28 Myr.

- Planetary bodies orbit their host star, often collide, merge and grow, or get scattered or ejected.

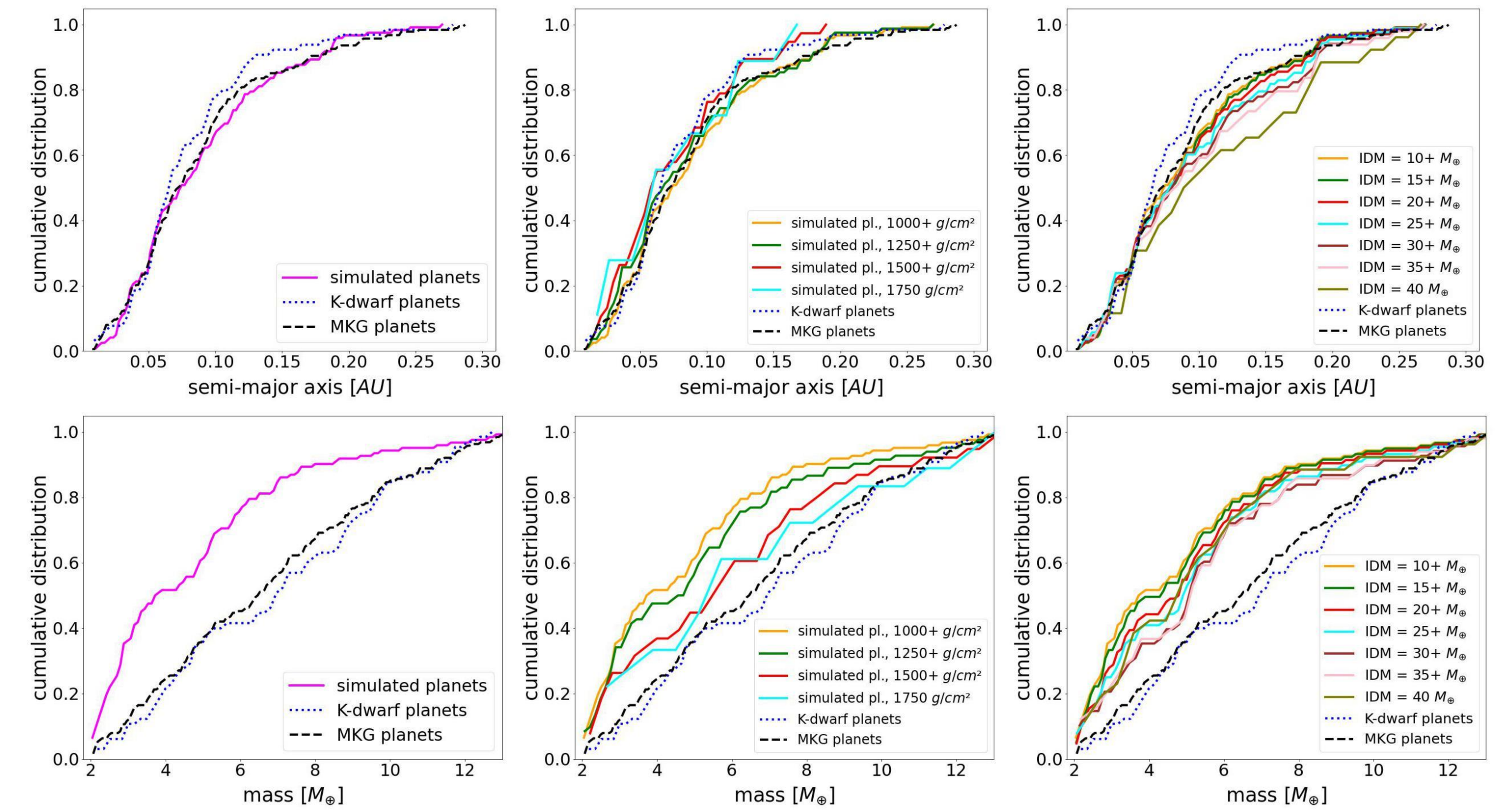
D) Final simulated population

- We managed to reproduce the main characteristics and architectures of the known systems and produce mostly long-term angular-momentum-deficit-stable, nonresonant systems with:
  - Disk mass of 15 M_{Earth} or higher
  - Gas surface density at 1 AU of 1500 g cm^{-2} or higher
- Our simulations also produced many low-mass planets with < 2 M_{Earth} not yet found in the observed population, probably due to observational biases.



Each line represents 1 planetary system with different initial disk mass and gas surface density.

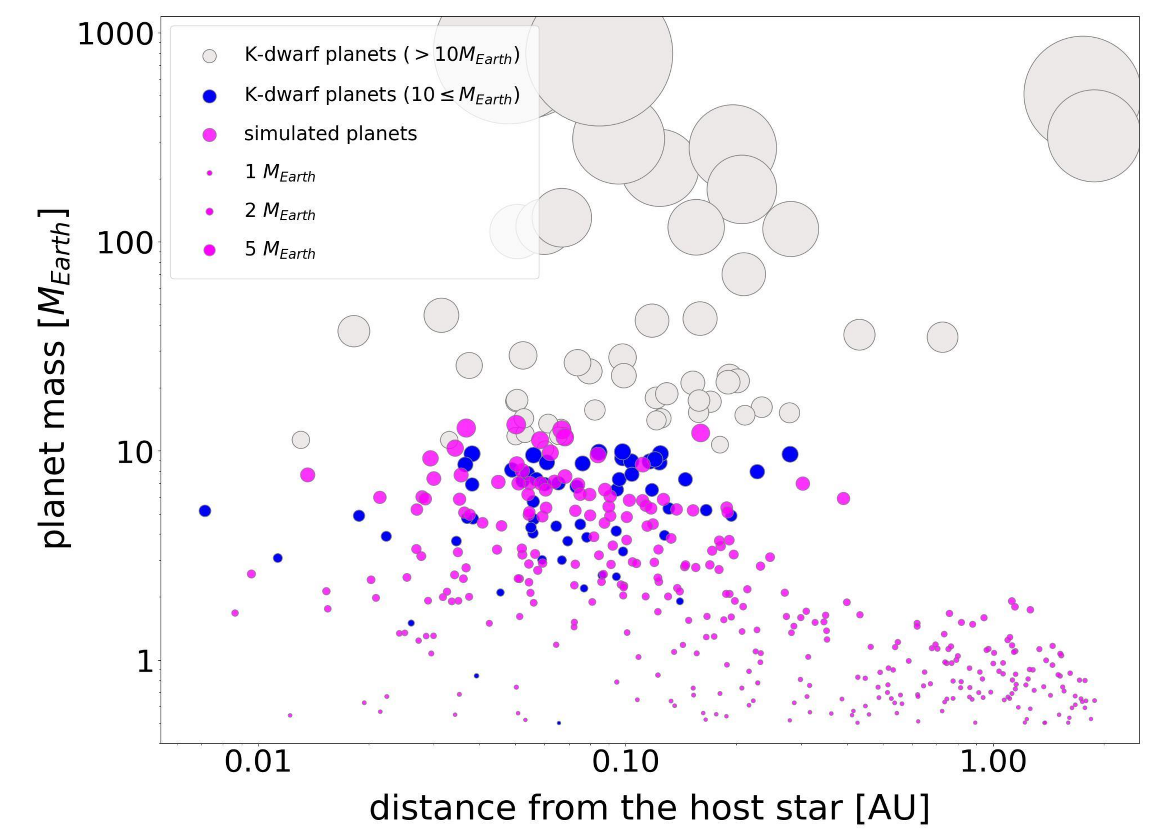
E) Comparison to the observed systems



- Cumulative distributions of a and m for the whole population, different gas surface densities, and initial disk masses are showing a preference towards less massive planets.

Conclusions

- With the suitable initial conditions, we managed to reproduce the main characteristics and architectures of the systems around K-dwarf stars.
- We produced mostly long-term stable, nonresonant systems.
- Earth-mass planets formed quickly, within a few Myr.



References

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2. Grimm, S. L. & Stadel, J. G. 2014, AJ, https://doi.org/10.1088/0004-637X/796/1/23
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