# M-dwarf planets form **rapidly** and **forget** their initial conditions

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## Why should we care?

- TESS is expected to find hundreds of M-dwarf planets
- Efforts to reverse-engineer initial conditions from modern observations may not be meaningful
- We should be cautious when using TESS data in the context of planet formation research

## Methods

- We run N-body simulations around a 0.2 $M_\odot$ star using the `MERCURY` code with the hybrid integrator
- 147 embryos per run with initial masses of 0.08 $M_\oplus$
- Solid surface density follows a uniform power law:

$$\Sigma = \Sigma_0 \, r^{-\gamma}$$

| Model | $\gamma$ | Gas disk? | $a_{\mathrm{init}}/\mathrm{AU}$ |
|---|---|---|---|
| Mix.1 | 0.6 | No | 0.033 – 0.26 |
| Mix.2 | 0.6 | Yes | 0.033 – 0.26 |
| Mix.3 | 0.6 | Yes | 0.033 – 0.52 |
| Frag.1 | 1.5 | No | 0.033 – 0.26 |
| Frag.2 | 1.5 | Yes | 0.033 – 0.26 |
| Frag.3 | 1.5 | Yes | 0.033 – 0.52 |

- **Mix Models:** Dust particles are well-mixed with the gas; solids mirror the viscously heated inner disk
- **Frag Models**: Dust sizes are fragmentation-limited; aerodynamic drag rearranges the solids

## Results

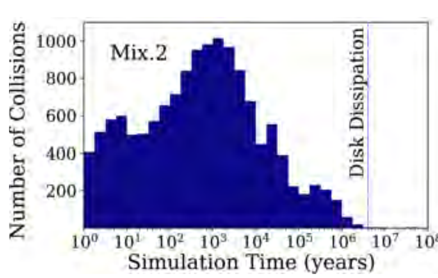


**Fig. 1:** The number of collisions for model Mix.2 with respect to simulation time. This plot is generally representative of all six models studied.

- Collisions peak at ~$10^3$–$10^4$ years
- Nearly all collisions occur within the simulation's first 1 Myr
- Planets mostly form before the gas disk dissipates

## Results (cont.)

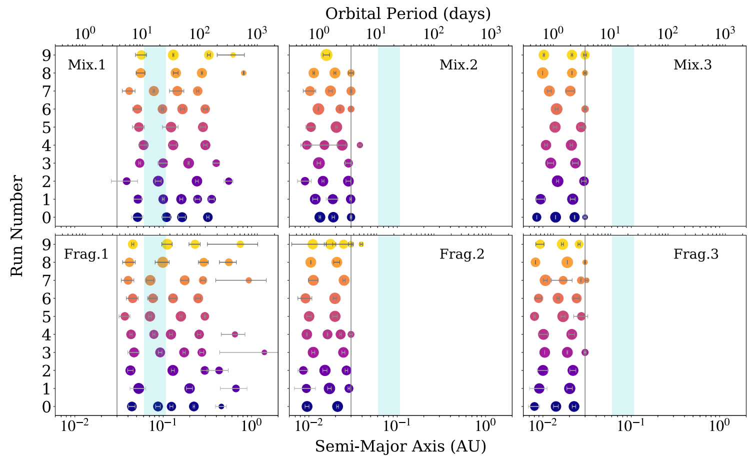


**Fig. 2:** Final planets from each run are given their own row and color. Error bars present each planet's apastron and periastron. The gray line at 0.03 AU represents the inner edge of the gas disk, and the vertical cyan band represents the habitable zone around the star.

- Models with a gas disk make planets that migrate inward
- All models that include gas produce planets with similar orbital characteristics

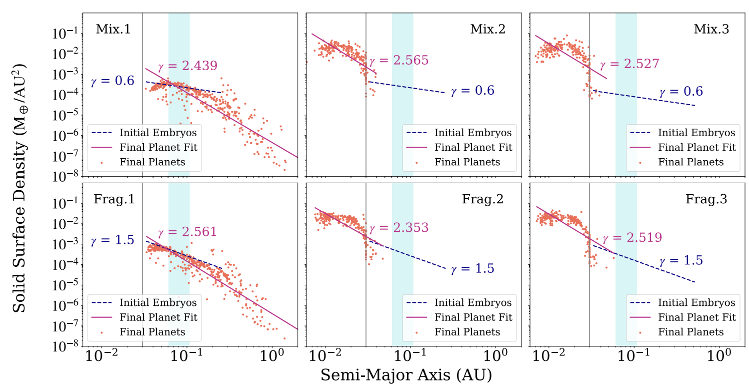


**Fig. 3:** Embryos are initialized according to a solid surface density profile that follows one of two uniform power laws. We compare the initial density profile of the embryos (blue dashed line) to the final planets formed (orange points) and fit the final planets to a new power law (pink line). The fitted power law index $\gamma$ for each model is presented.

- For all models, final density profiles are completely different from the initial embryo distribution
- The presence of a gas disk does not affect this result

## Conclusions

- Planets form quickly, long before the gas dissipates
- Planet formation reshapes the solid distribution and destroys memory of the initial conditions
- However, planets remember whether gas was present during formation

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