Dust formation in the outflows of catastrophically evaporating planets

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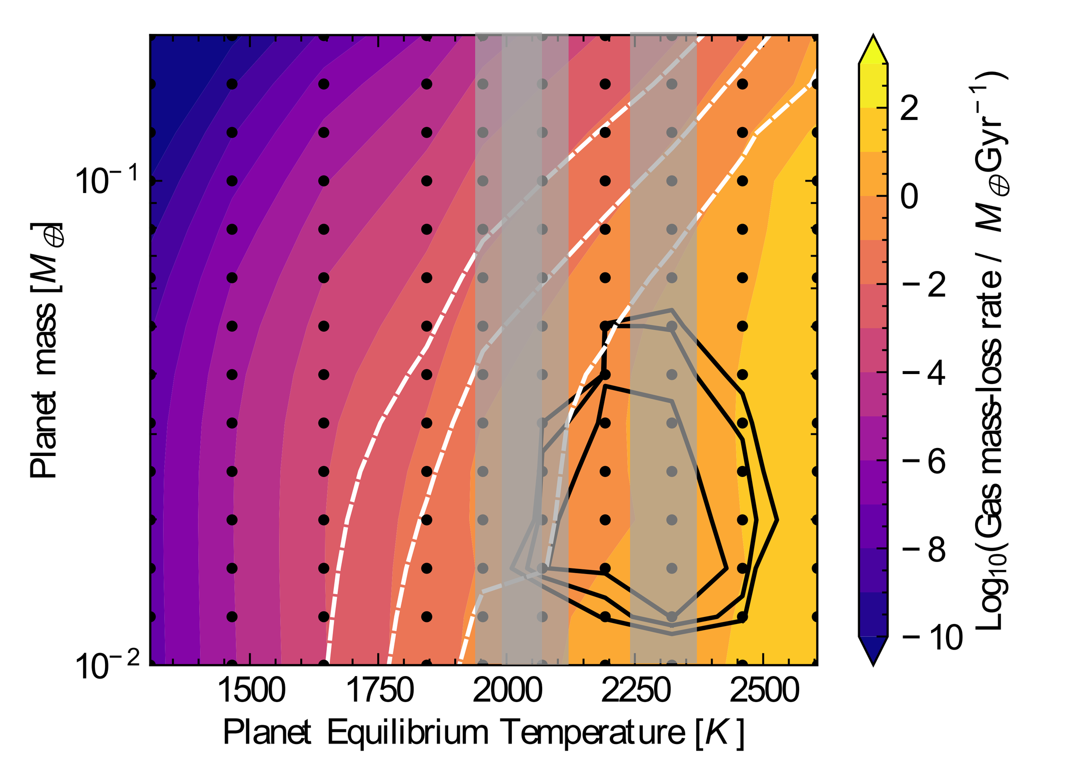
Evaporating, ultra-short period rocky planets produce dusty winds as their cores evaporate at the end of their lives.



Mass loss rates from evaporating, ultra-short period rocky planets

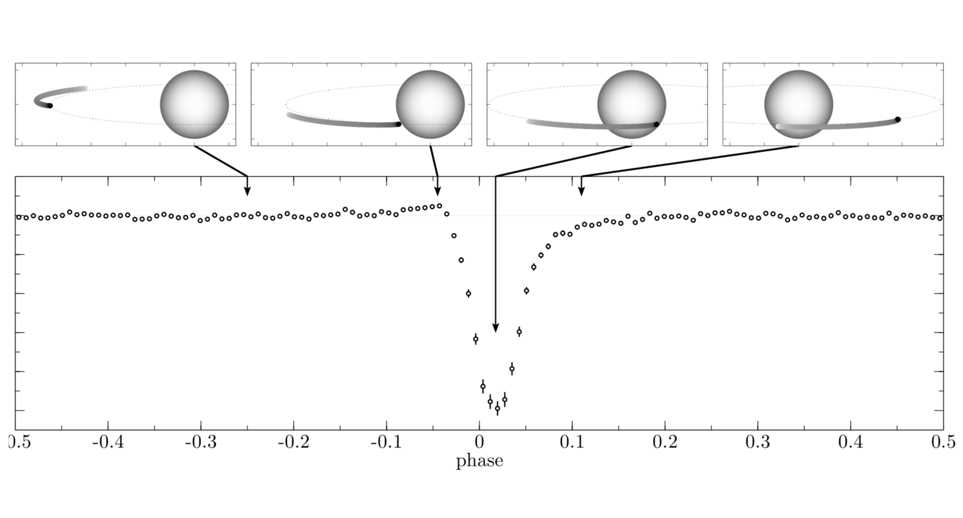
Black contours show regions were the winds are *dusty*

Grey bands show the approximate temperatures of known evaporating planets.

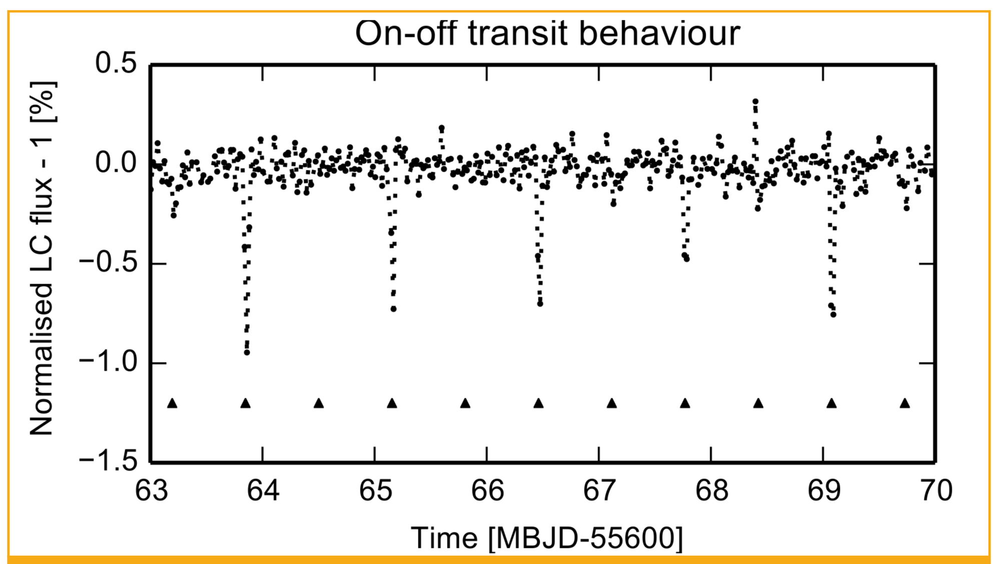
White contours show lifetimes of 10, 1 and 0.1 Gyr.

Introduction

- Ultra-short period planets can be so hot that their cores evaporate
- This produces time-variable, dusty tails that can be detected through transits
- Provides a rare window into planetary interiors
- **Goal**: understand how the dusty outflows are produced



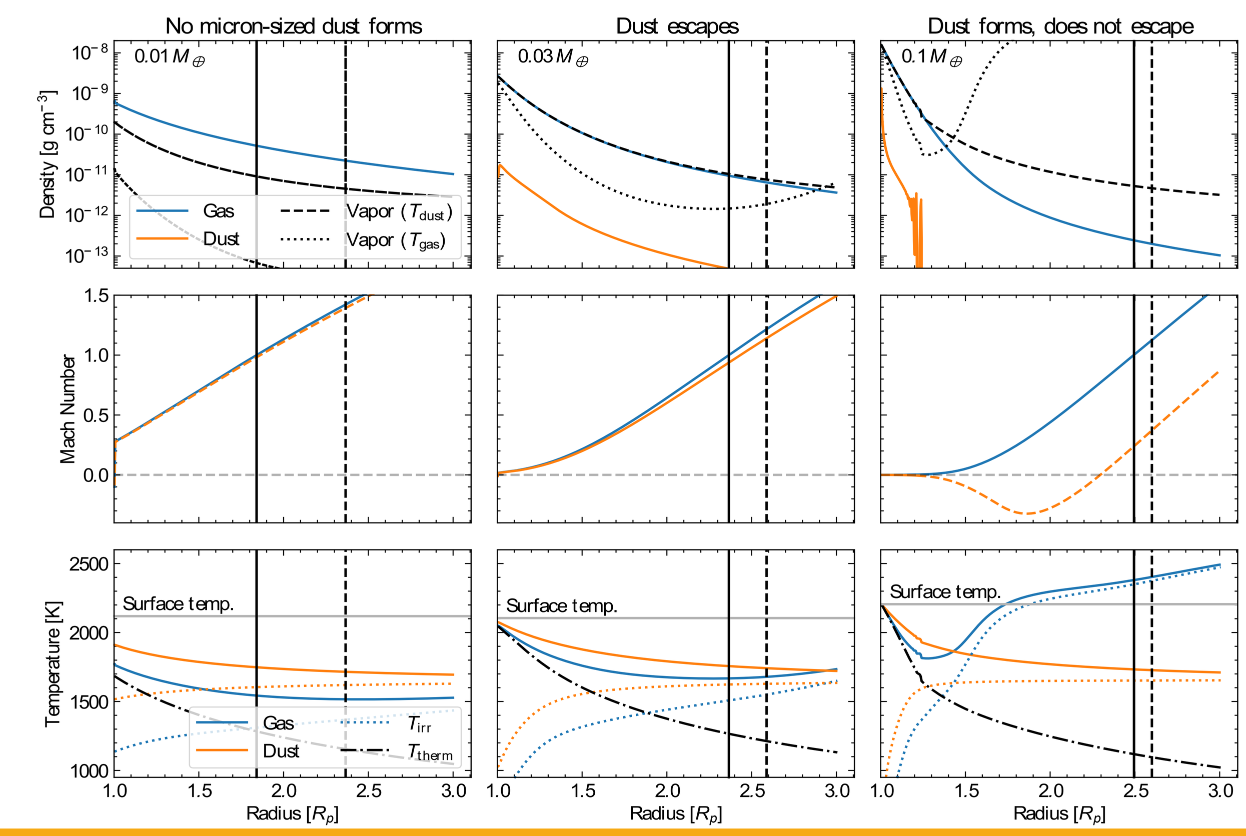
Average transit of KIC 1255b, showing the asymmetric tail and scattering peak [1]



Time-variable transits of KIC 1255b, showing on-off behaviour [2]

Method & Results

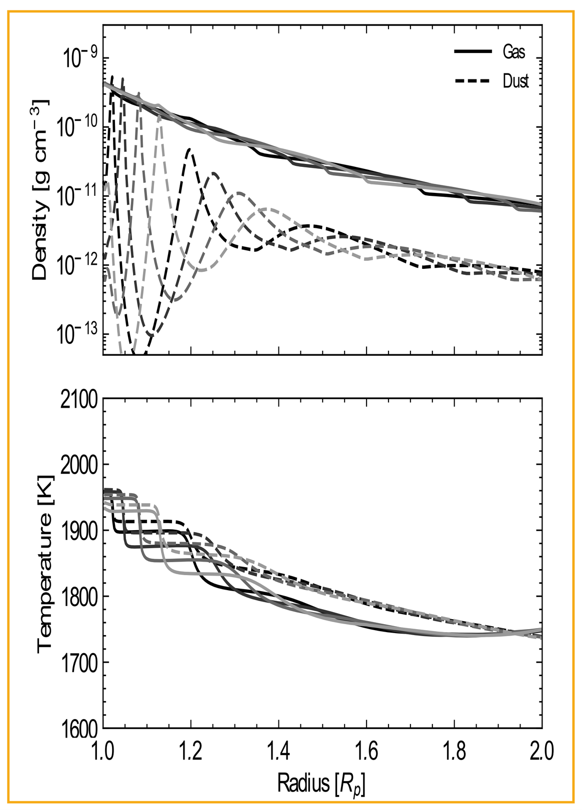
- Conducted 1D radiation-hydrodynamic simulations of winds from the substellar point (using aiolos [3])
- Including a simple model of dust formation, destruction and dynamics, based on condensation physics and assuming 1 micron grains.
- We find dust cools below the planet surface temperature, allowing it to condense readily
- For the lowest mass planets, the winds remain free of micron sized dust because they form too slowly
- For the highest mass planets dust can form, but the grains evaporate before they escape



Dust-forming winds from the substellar point. Dust forms because the dust temperature is lower than the planet temperature. However, for low mass planets the dust does not have sufficient time to grow and for too massive planets the dust evaporates before it escapes.

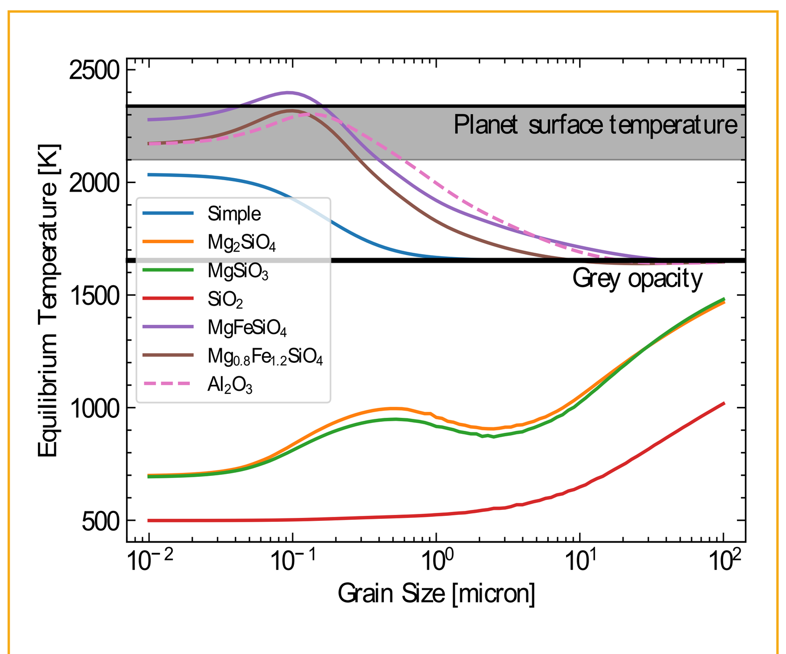
Variability

- Variability is produced because high optical depths reduce the ability of the dust to cool, disfavouring its formation
- Produces cycles where dust is forms, increasing the optical depth, causing dust to stop forming until the existing dust is carried away in the wind
- 'Clumps' form and are carried away on a flow time-scale (10^4-10^5 s)
- Occurs when dust formation is rapid



Composition

- Dust forms when it is cooler than the planet's surface
- Grains with high optical opacities are too hot to form at small sizes.
- Only Fe-poor silicates, with low optical opacities are cool enough at small sizes
- **But**: Fe-rich grains evaporate more easily
- Expect dust composition and temperature are linked through a feedback process



Equilibrium dust temperature for different grain sizes and materials

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References

1. *van Werkhoven et al. (2014)*
2. *van Lieshout et al. (2014)*
3. *Schulik & Booth 2023, in review*
4. ***Booth, Owen & Schulik 2023, MNRAS***

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