Hydrodynamic Mass Loss from Disintegrating Exoplanets

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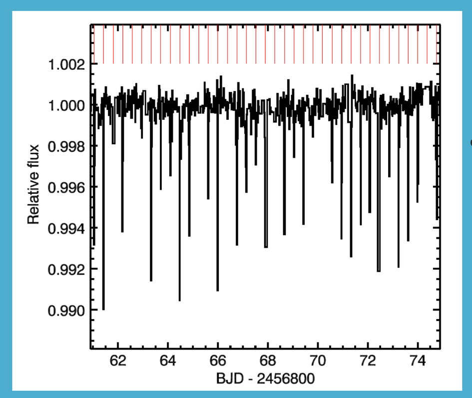
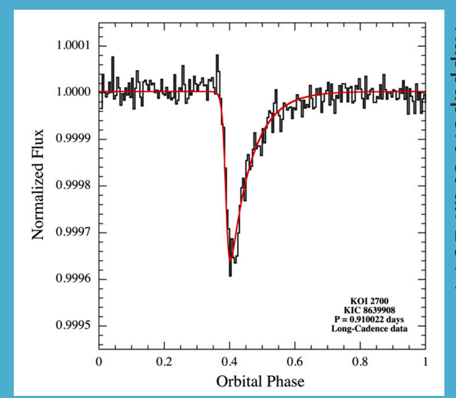
What are Disintegrating Exoplanets?

Disintegrating planets are rare planetary systems discovered during the Kepler/K2 missions via their **unique transit signal**. The planets are low mass, rocky bodies ejecting vaporized surface material at a rate of roughly **one earth mass per gigayear**. These planets have short orbital periods (less than one day) which leads to **high thermal energy flux** thought to be responsible for the **extreme hydrodynamic mass loss**.



Sanchis-Ojeda et al. 2015

Variable Transit Depth



Rappaport et al. 2014

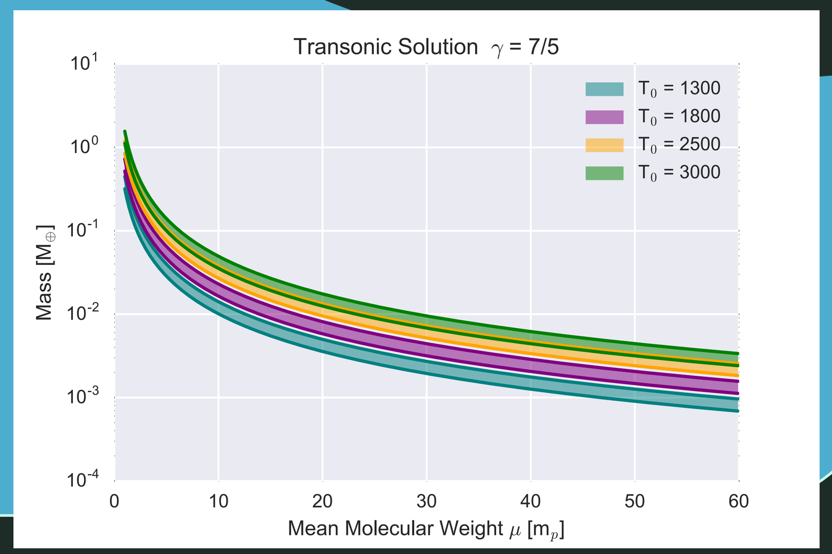
Asymmetric Transit Profile

Motivation

The **search for life** on extrasolar planets relies predominantly on the detection of **biosignature gases**. To differentiate true biosignature gases from **false positives** requires an understanding of abiotic gas production rates. Models of abiotic gas production depend not only on planet mass but also planet composition. **Disintegrating planets** offer a very rare glimpse of ***in situ* planet composition** outside of our solar system. This allows us to test the assumption that **planet composition is the same as the host star**, and provide much needed data to benchmark and/or further our understanding of **planet formation**.

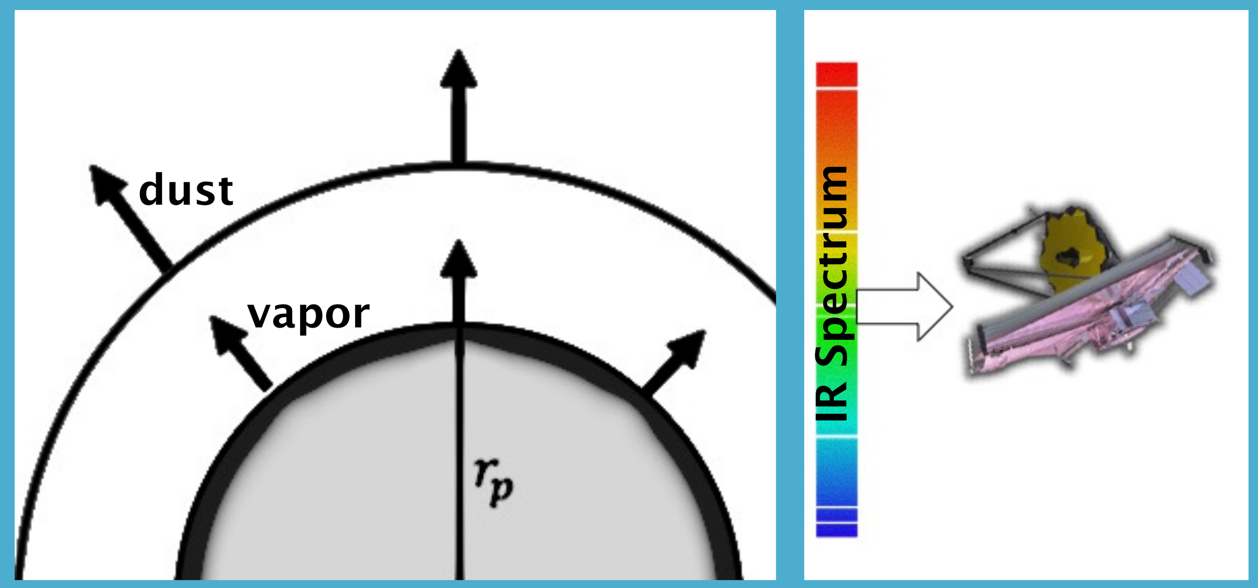
Is it Steady State?

Disintegrating planets are thought to disintegrate due to **parker-type thermal winds**. These winds are driven by pressure gradients in the planet's atmosphere caused by high temperatures relative to the effective gravity. The canonical parker wind solution, however, is a steady state solution that leads to an unrealistically **fine tuned solution space** when applied to disintegrating planets. Instead of a steady state solution, we expect **aperiodic or sporadic mass loss** from these planets.



Modeling

As vaporized surface material thermally expands, it **cools and condenses** into dust grains. These **mineral grains** have **unique spectral resonances** in the infrared that can be used to identify the surface composition of the planet in question.



Coupling hydrodynamics to mineral condensation requires the following non-steady state equations:

1d Conservation Equations

$$\partial_t \rho + \nabla_r(\rho u) = 0$$

$$\partial_t(\rho u) + \nabla_r(\rho u^2 + P) = -\rho \nabla_r \Phi$$

$$\partial_t(\rho e_{tot}) + \nabla_r[(\rho e_{tot} + P)u] = -\rho u \nabla_r \Phi + L$$

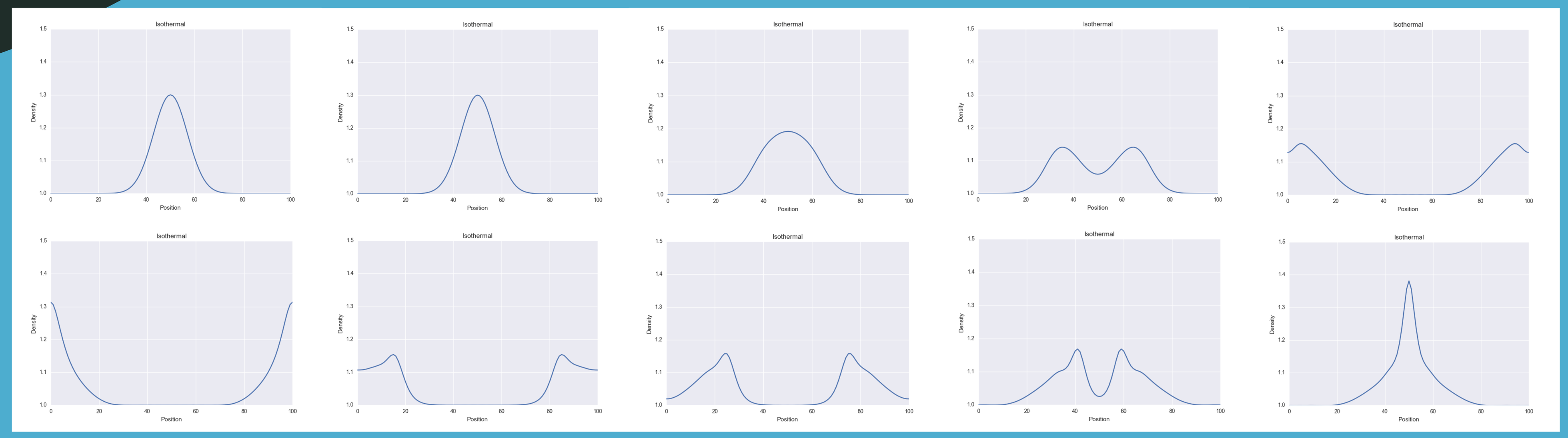
Update Algorithm

flux through interface

source terms

$$q_i^{n+\frac{1}{2}} = q_i^n - \Delta t \frac{f_{i+1/2} - f_{i-1/2}}{\Delta x} \qquad q_i^n = q_i^n + Q$$

conserved quantity



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