Particle Trapping in M Dwarf Disks

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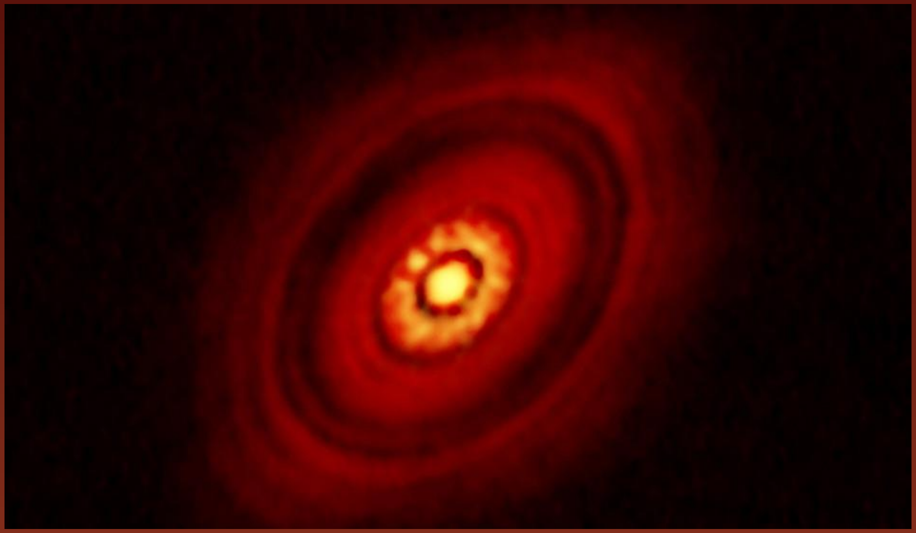
Observation of Gaps in Disks

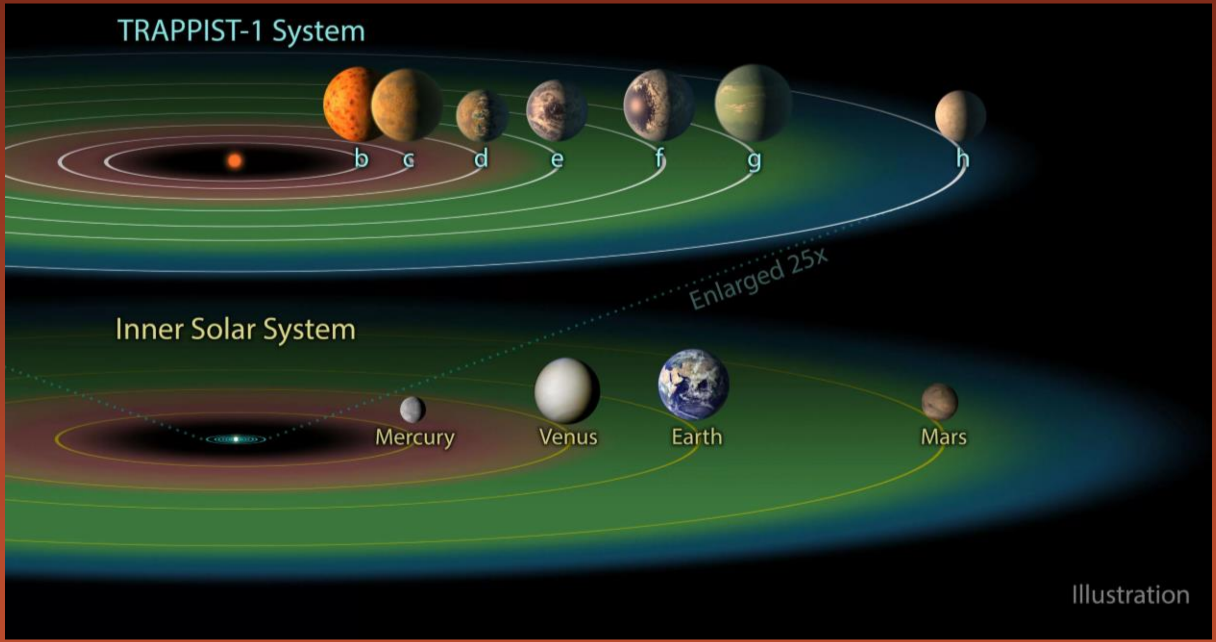

(credit ALMA/ESO/NAOJ/NRAO)

- HL Tau
  - ≤1-2Myr old disk (Brogan et al. 2015)
  - ALMA imaging shows significant structure
  - Shows that planet formation can start early on

- Isotope Reservoirs
  - Likely that Jupiter formed very early in solar disk (<1Myr)(Kruijer et al. 2017)
    - Reservoirs of non-carbonaceous and carbonaceous meteorites
    - Early and rapid growth would have created a large gap in the disk

Volatile Content of Terrestrial Planets

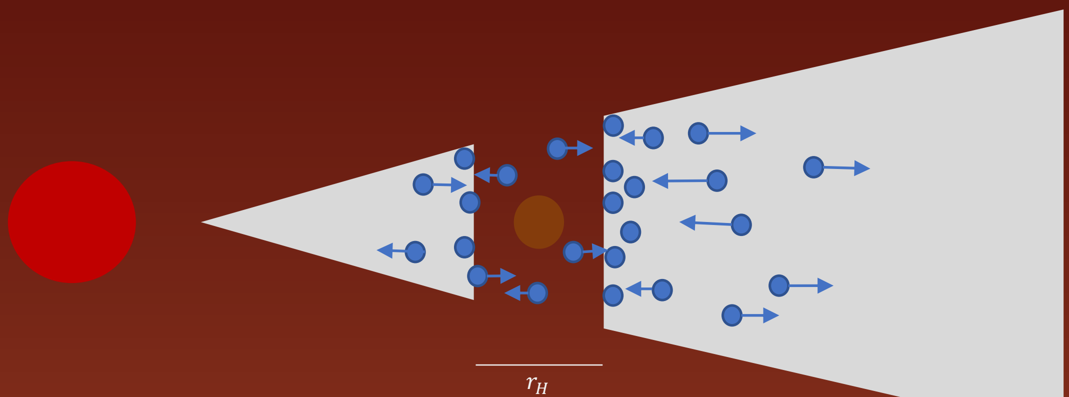
- Volatile content influenced by where a planet forms
- Snowlines form boundary beyond which water is ice
- Inner solar system is water-poor, outer is water-rich
  - Earth is $\leq$0.1wt% water (Mottl et al. 2007)
- Planets around TRAPPIST-1 have resonant orbits (Gillon et al. 2016, 2017)
  - Implies they migrated inwards to their present orbits
- TRAPPIST-b and -c are likely ~7wt% water, while planets d-h are >50wt% (Unterborn et al. 2018, in review)

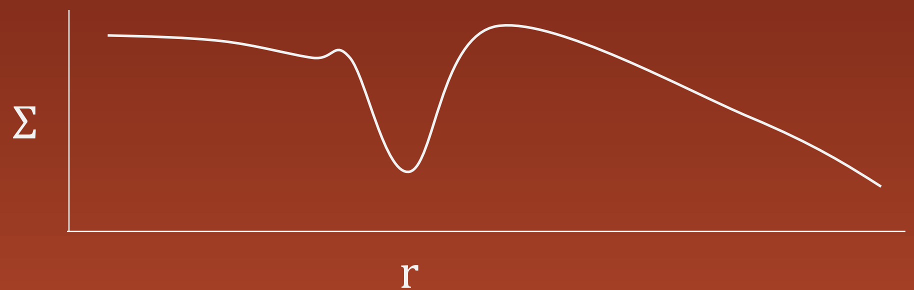


(credit Cal-Tech JPL/NASA)

- Implies –b and –c formed interior to snowline
- Still higher wt% water than Earth, suggesting volatile gradient is less sharp in M Dwarf disks

Particle Trapping





- Once a planet reaches pebble isolation mass, it carves out a gap in the disk
- Normally, particles drift toward negative gradient in a disk
- Gap changes pressure gradient in the disk
- Particles accumulate just outside gap from drift
- Particles diffuse out of pressure bump, too
- $t_{drift} = \frac{\Delta r}{\upsilon_{part,r}}$
- $t_{diff} = \frac{\Delta r^2}{D_{part}}$
- $\frac{t_{diff}}{t_{drift}} \propto \Delta r$

Disk Evolution Code

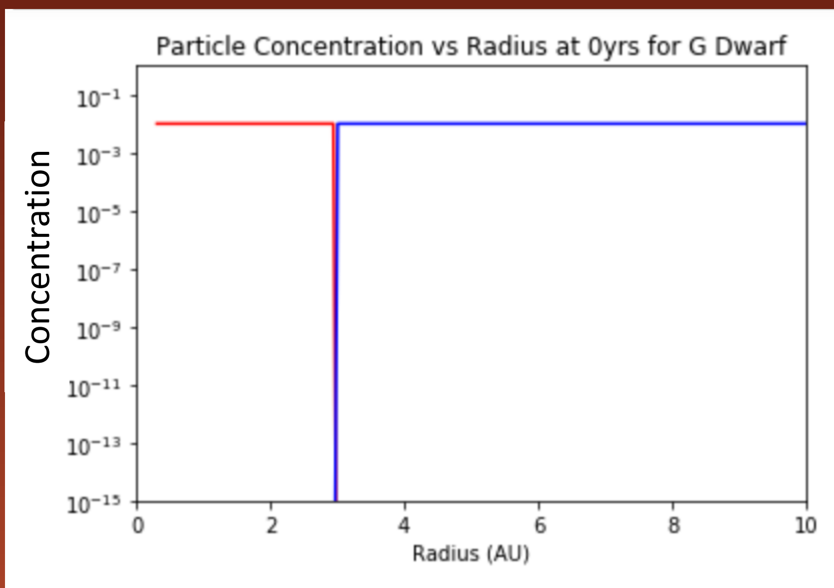
- 1D disk evolution code in Fortran
  - Includes particle transport (Desch et al. 2017,2018 in review)
  - Passive temperature profile
- Gap
  - Opens when planet reaches pebble isolation mass (Lambrechts et al. 2014, Ormel et al. 2017)
    - G Dwarf: 30 Earth masses at 3 AU
    - M Dwarf: 1 Earth Mass at 0.3 AU
  - Planet does not migrate
- Ran disk evolution for two million years to see how particles diffuse and drift across gap and compared timescales

Results

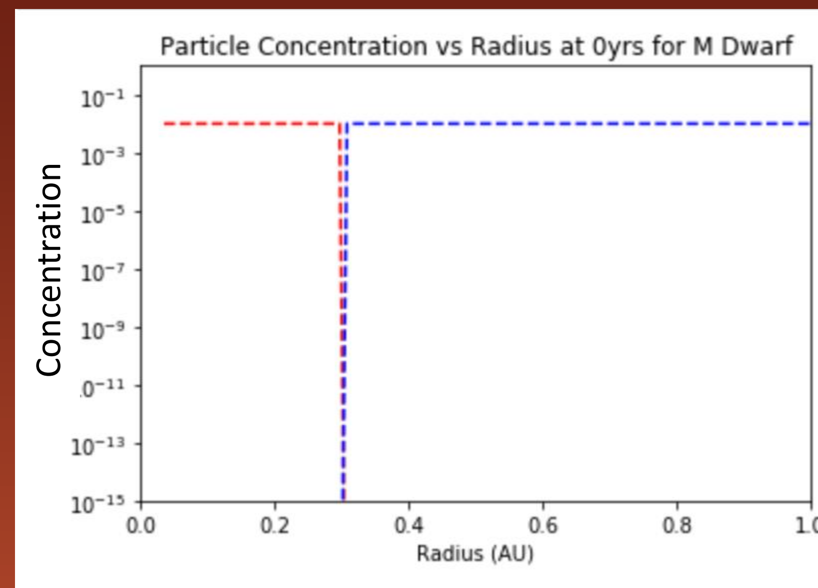
At t=0Myr

(0.5cm radius, “red” particles are interior to gap, “blue” are exterior)

G Dwarf disk



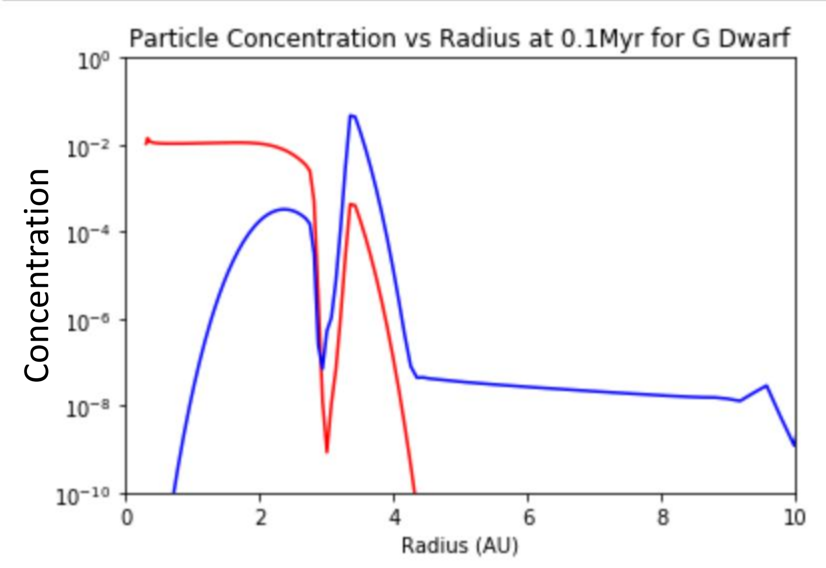
M Dwarf disk



Results

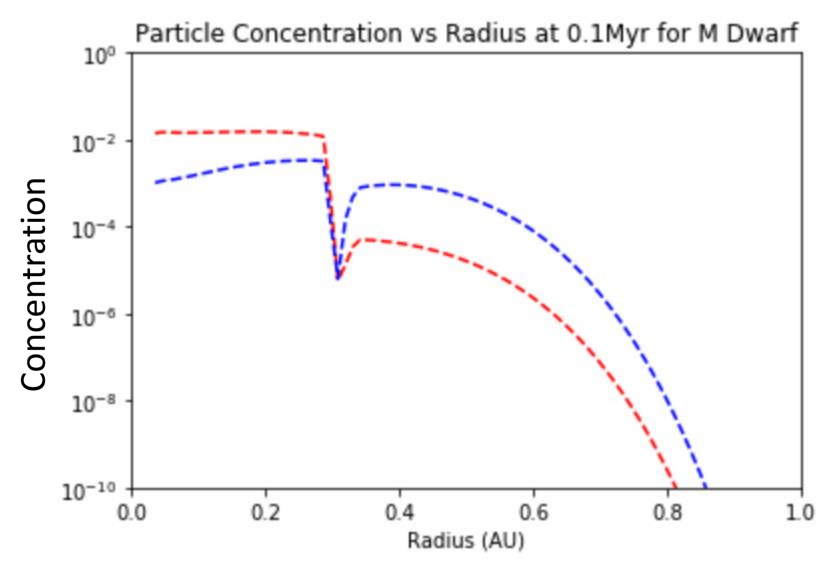
At t=0.1Myr

G Dwarf disk



$$\frac{t_{diff}}{t_{drift}} = 1.364$$

M Dwarf disk



$$\frac{t_{diff}}{t_{drift}} = 0.118$$

Conclusions

- We wanted to test efficiency of particle trapping in G Dwarf and M Dwarf disks
- We found that G Dwarf disks are more effective at trapping particles than M Dwarf disks
- Particles in M Dwarf disks likely diffuse better

Acknowledgements

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Thank you