Signs of Migrating Icy Worlds in the Radius Valley

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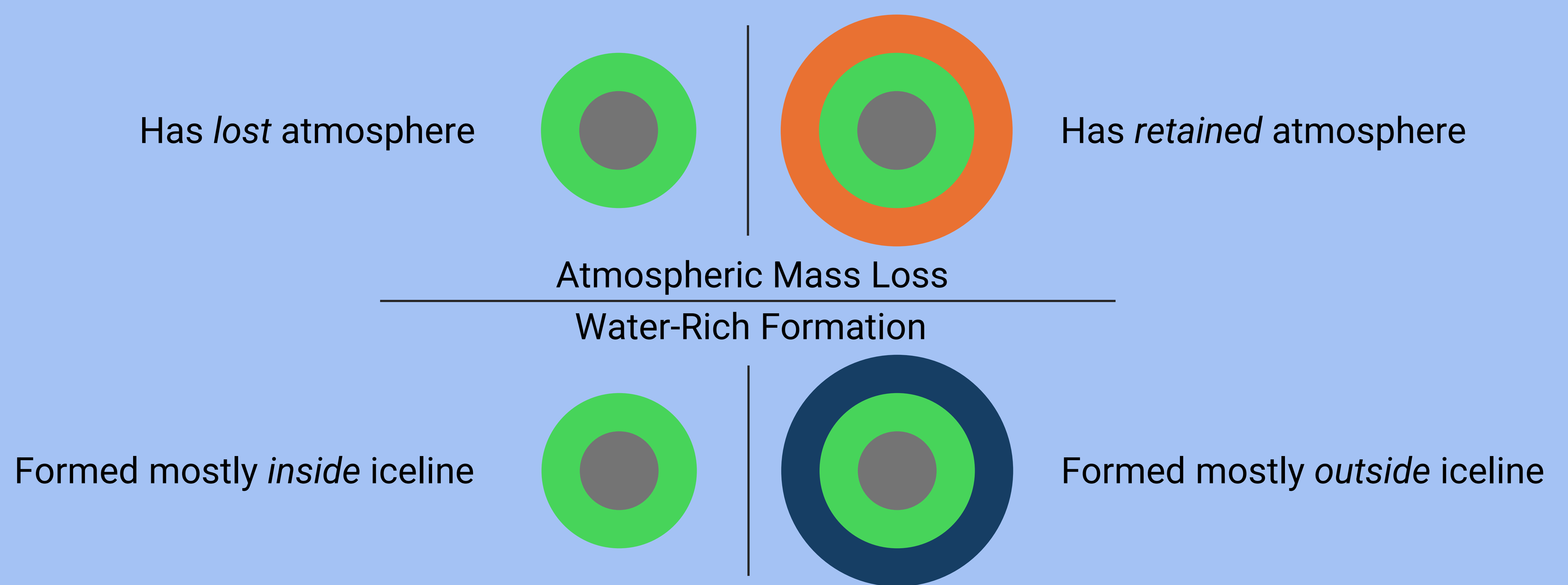
ALL RESULTS NOT FINAL AND *WILL* CHANGE BEFORE PUBLICATION!

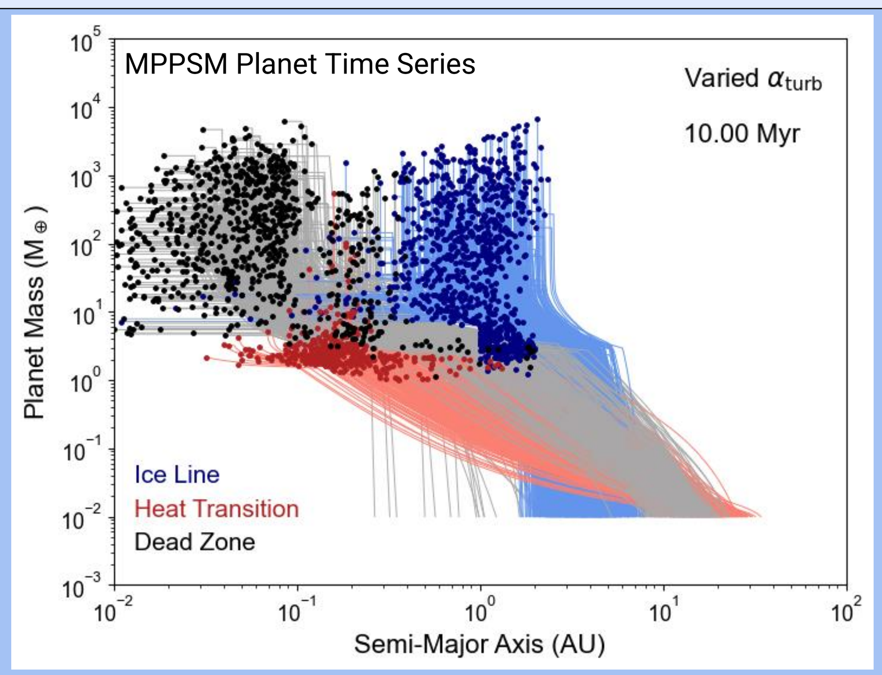
Radius Valley

- Distribution of planetary radii is bimodal – "Radius Valley"[1]
  - ~1.3 $R_\oplus$ super-Earth peak and ~2.4 $R_\oplus$ sub-Neptune peak[1]
  - Super-Earth ρ consistent w/ Earth-like
  - Sub-Neptune ρ consistent w/ H/He OR water envelope
- Sub-Neptune composition depends on valley formation
  - Atmospheric mass loss → H/He-rich
  - Water-rich formation → water-rich
- FGK slope w/ instellation consistent w/ envelope mass loss[2,3]
- M slope different v. FGK stars[4], possible water-rich formation
- Both mechanisms could contribute[5]



Planet Population Synthesis

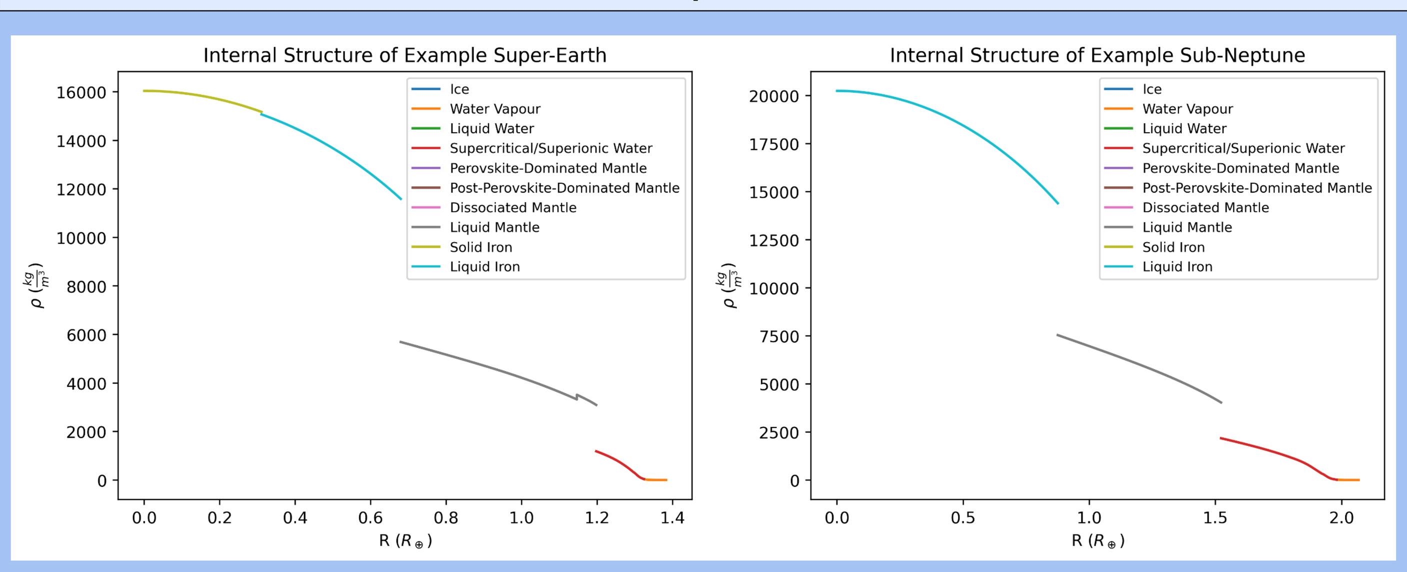
- Simulate planet formation, create synthetic population
- McMaster Planet Population Synthesis Model (MPPSM)[6]
  - Planetesimal accretion in disk around sunlike star
  - One lunar-mass embryo/disk
  - Power-law disk evolved via turbulent viscosity
  - Disk wind-driven advection and mass loss
  - Planets form in planet traps where disk conditions change[7]
    - Ice Line: Water vapour → condensed
    - Heat Transition: Heat via viscous dissipation → irradiation
    - Dead-Active Zone: MRI inactive → MRI active



Alessi & Pudritz (2022) Fig. 7[6]

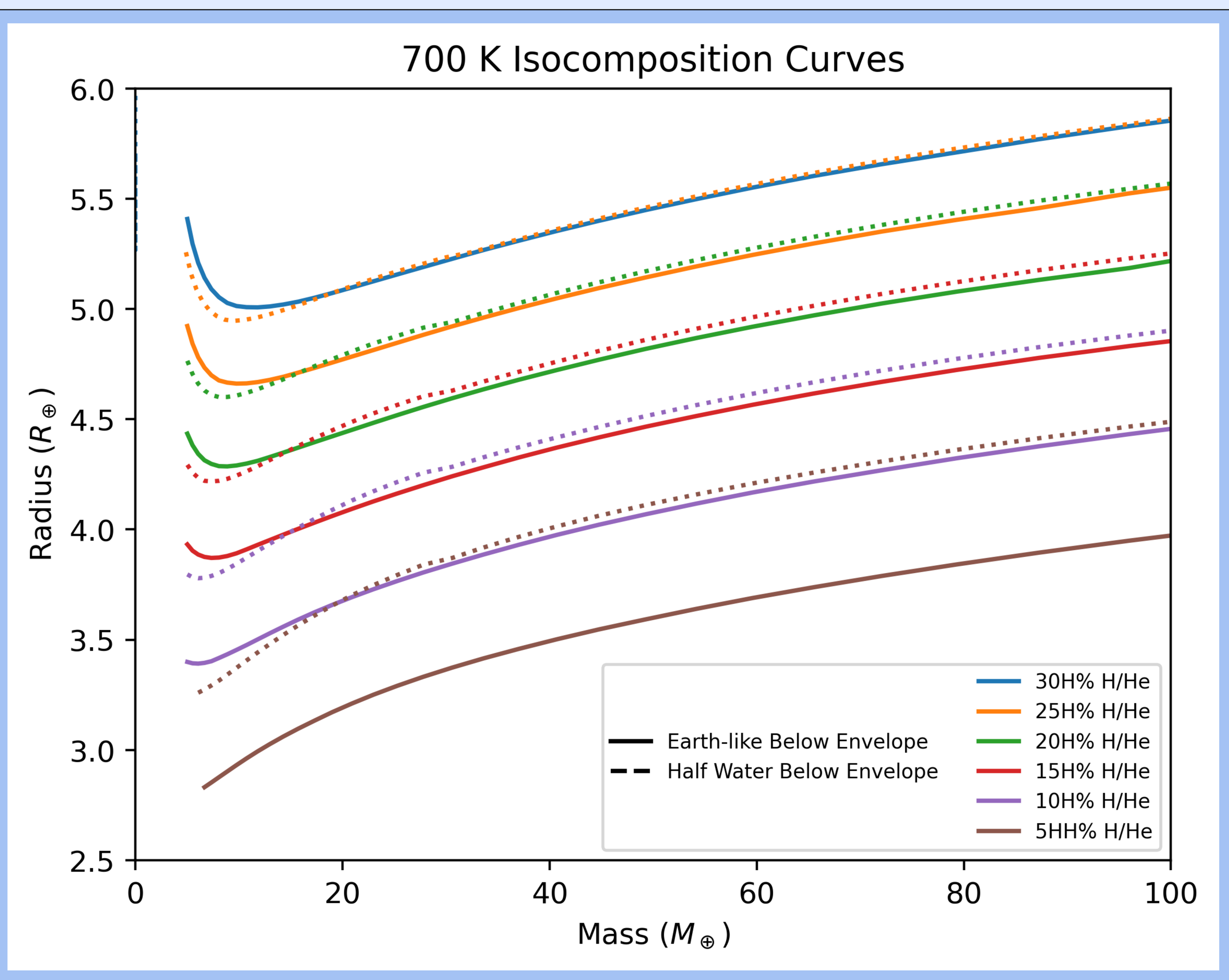
Interior Structure Updates

- Determine planetary radii from MPPSM output parameters[7]
- Now use most modern Equations of State (EOS)[8-25]
  - Experimental measurements of ρ using diamond anvils[22]
  - Apply Density Functional Theory (DFT) to high pressures[23]
- More advanced model
  - Mantle composition via Gibbs free energy minimization[13]
  - Non-grey irradiated atmosphere[26-29]
  - Thermal effects (including melting) within mantle, core[8-25]
  - FeS in the core[21,23]
  - Prescription for rotation[30-31]
- Transit radii calculated to compare to observations[26]



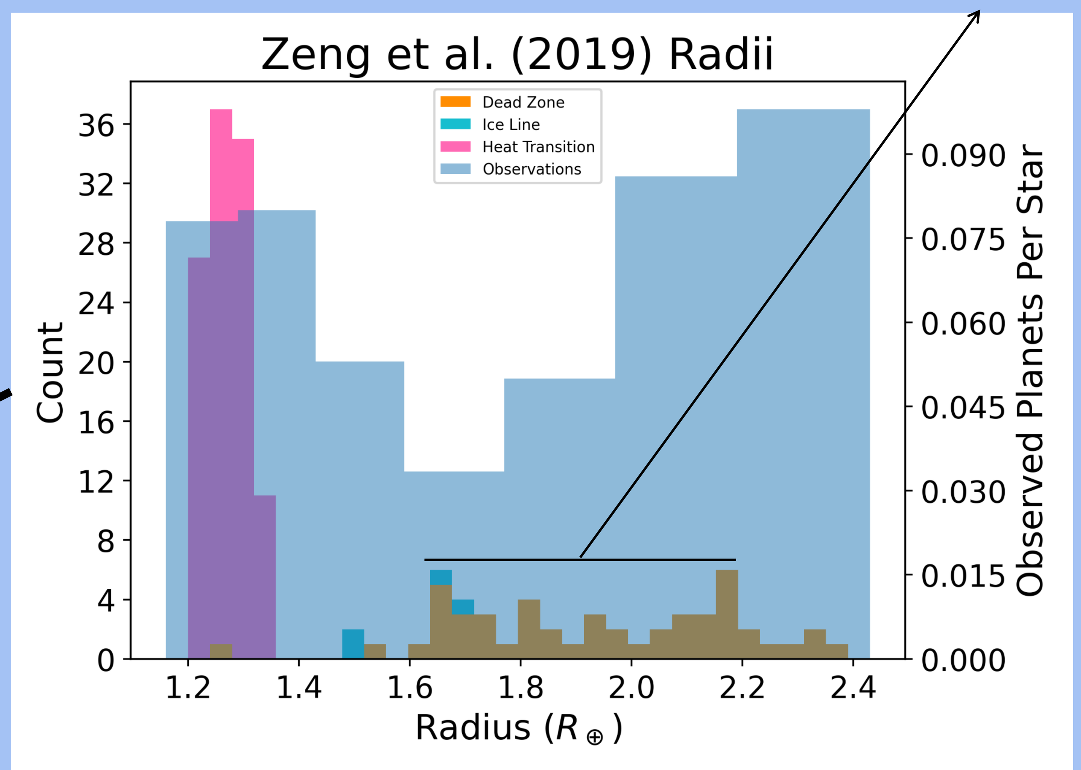
New Mass-Radius Curves

- Radii calculated for varying masses, compositions
- Current mass-radius curves old EOS or not made for high T



Synthetic Radius Valley

- Calculated radii of MPPSM planets w/ new interior structure
  - Is radius valley replicated *without H/He-rich planets*?
- Peak radii approximated but relative occurrence incorrect
  - Water worlds could be *secondary* FGK sub-Neptune source
- Updated interior structure model *required* for radius valley
- W/o winds, no radius valley b/c less migration



Too broad

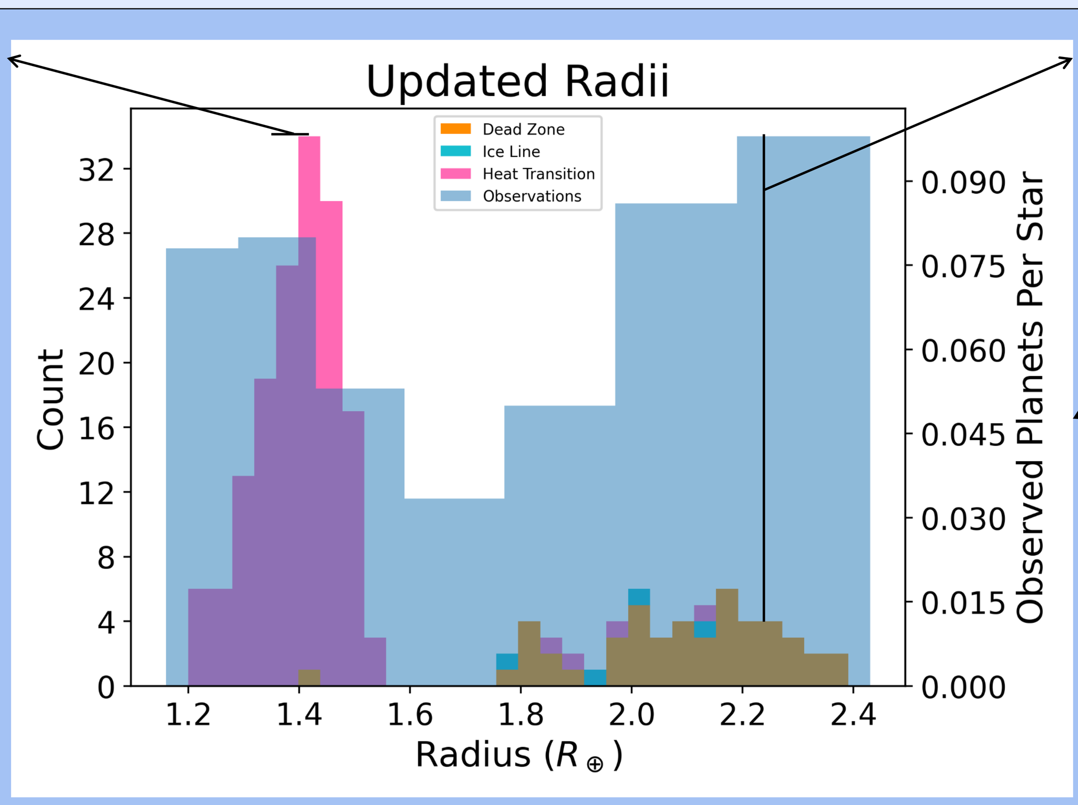
Observations from Fulton et al. (2017)[1]

Update Interior Structure Model

Planets too hot, too water-rich

H/He-enveloped planets dominate

Observations from Fulton et al. (2017)[1]



Future Work

- Incorporate metals in H/He envelope
- Non-radiogenic heating
- Implement active-dead zone boundary
- Create and run MPPSM for M dwarf stars
- Statistically quantify synthetic-observational discrepancy
- Apply improved interior structure to MPPSM advances
  - Pebble accretion, new wind prescription, N-body, etc.

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