Metallicity Assessment Quantifying Exoplanet Embryonic Numbers (MetallicA QuEEN)

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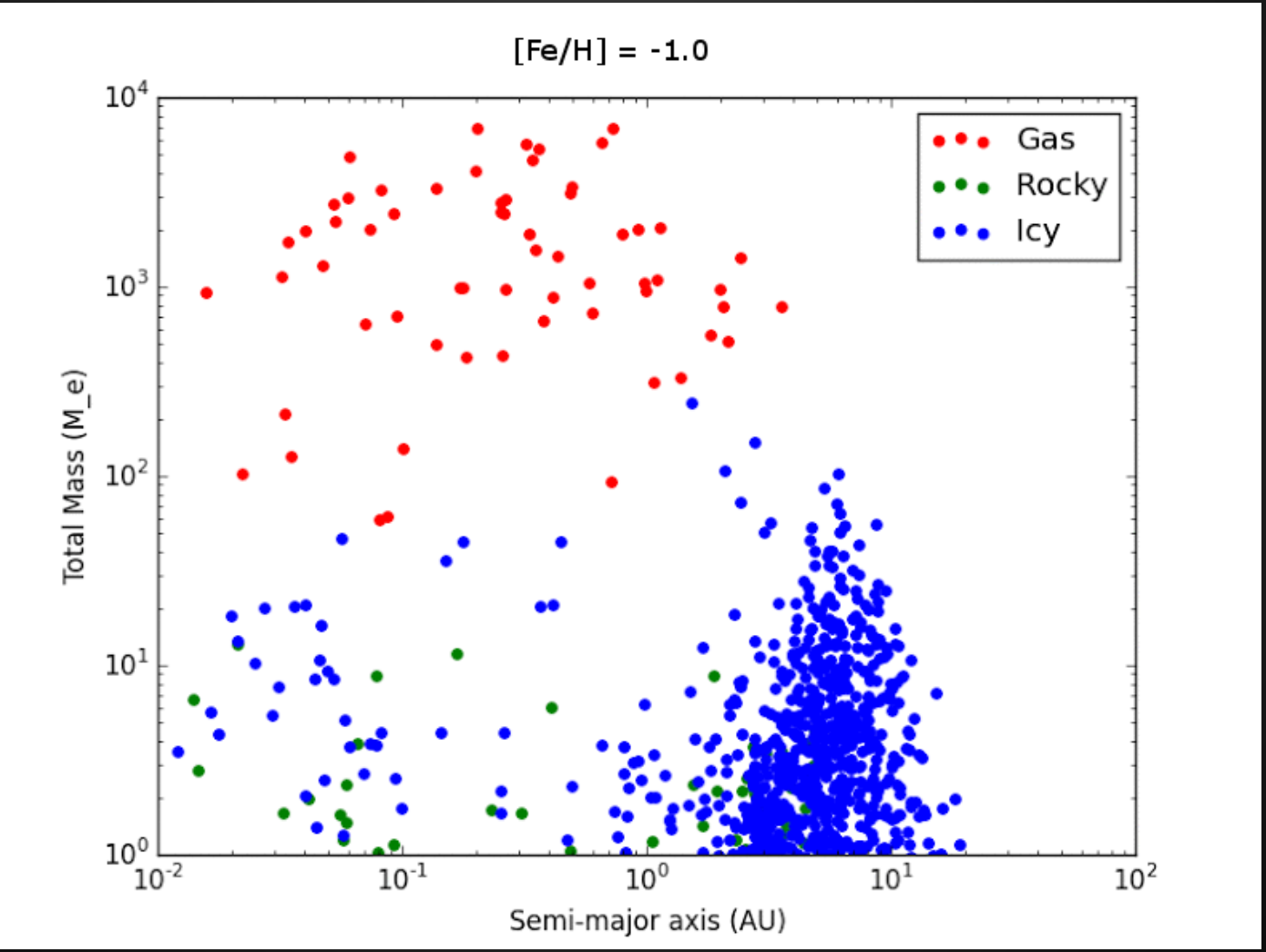
Problem

- Project Goal
  - Understand planet formation, specifically how it applies to the metallicity of the protoplanetary disk
- Objective
  - Demonstrate how varying metallicities and dust to gas ratios affects planet formation model outputs
- Science Questions
  - How does increasing the dust-to-gas ratio affect planet formation?
  - How does metallicity affect planet formation and migration?

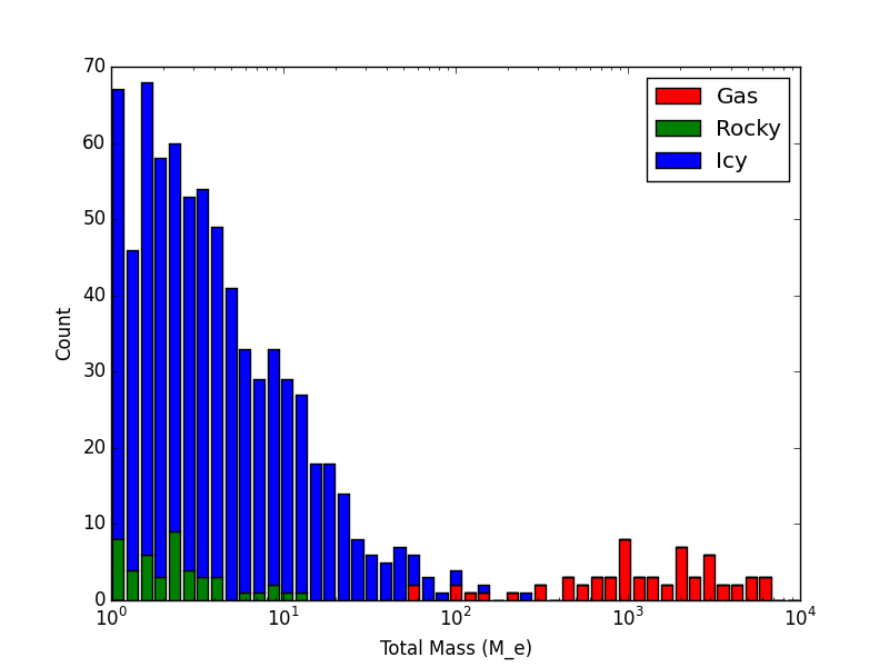
Hypothesis and Methods

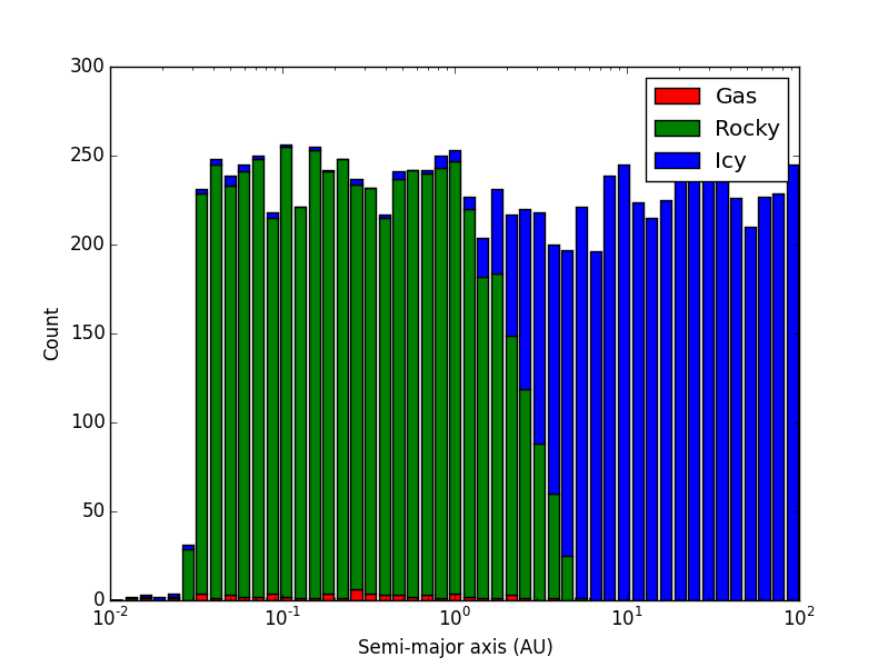
- Hypothesis
  - If the metallicity is increased, then planet mass and size will increase
- Methodology
  - Run the program with nominal parameters, but vary dust-to-gas ratio (D/G) and/or metallicity [Fe/H] levels
    - degeneracy in these two parameters
  - Vary metallicity levels while holding other parameters constant
  - Compare results of each case

Metallicity Results: **How does the planet population change with metallicity?**

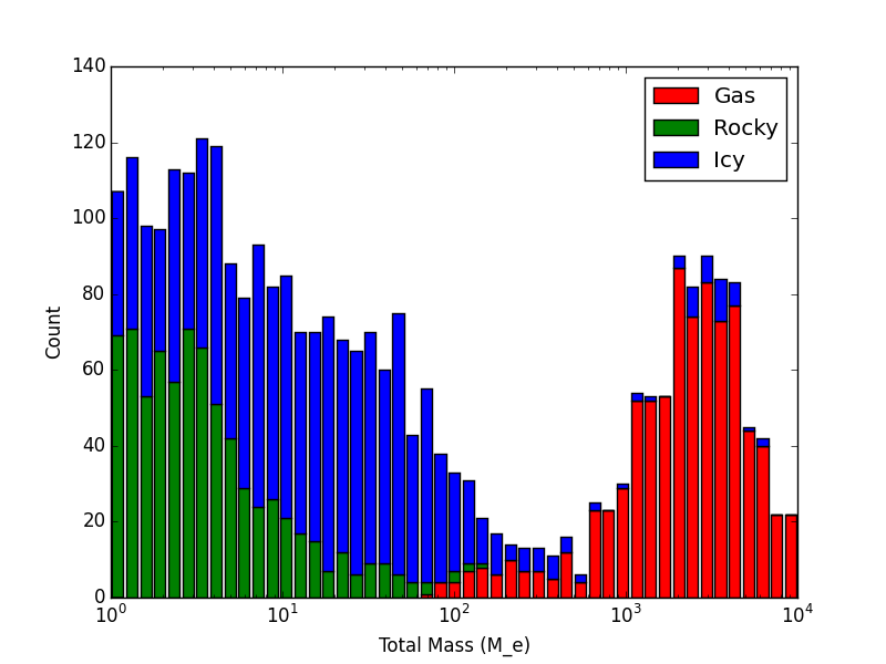


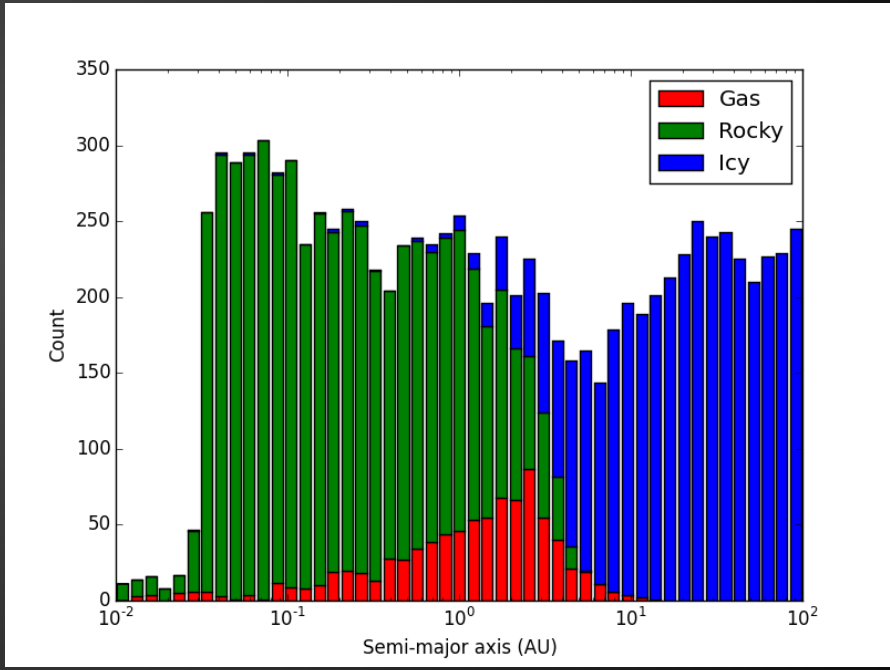
Metallicity Results: [Fe/H] = -1



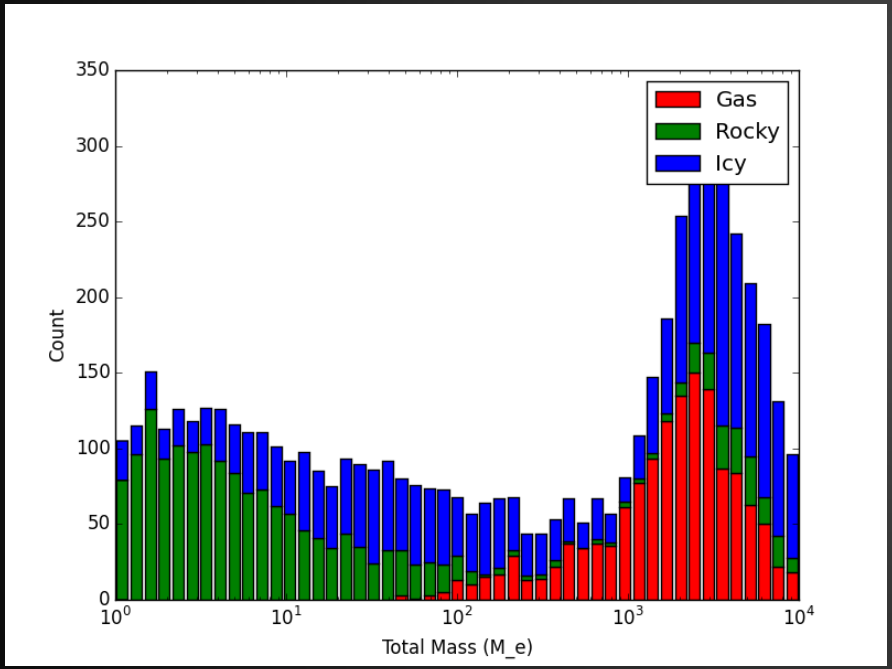


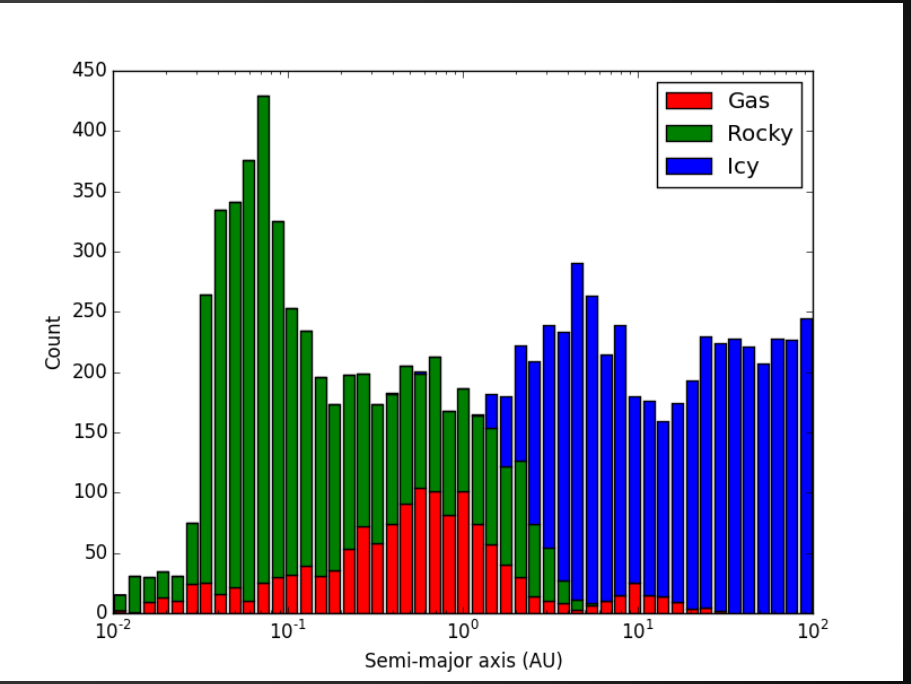
Metallicity Results: [Fe/H] = 0



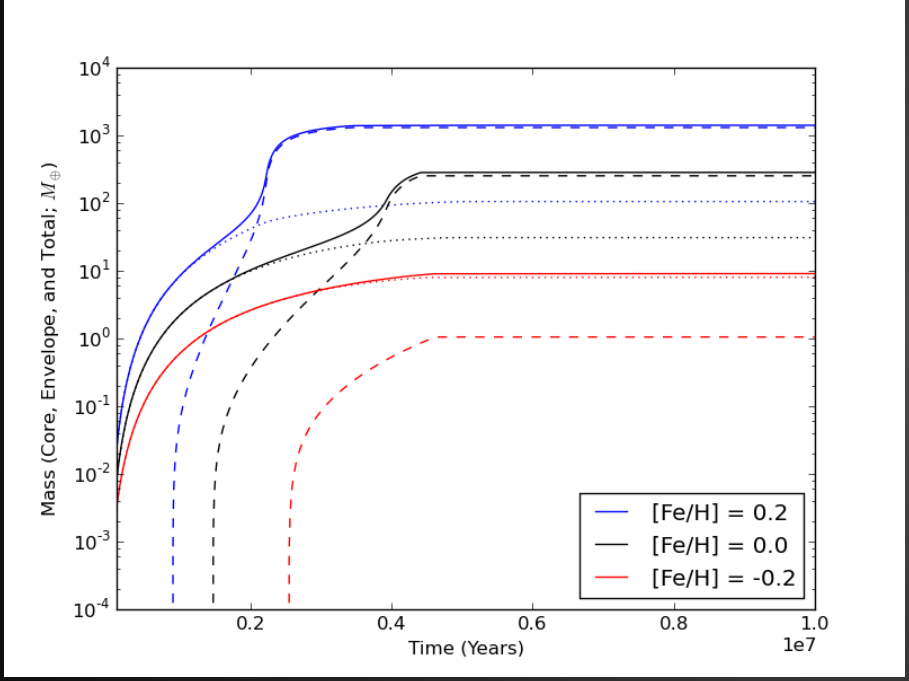


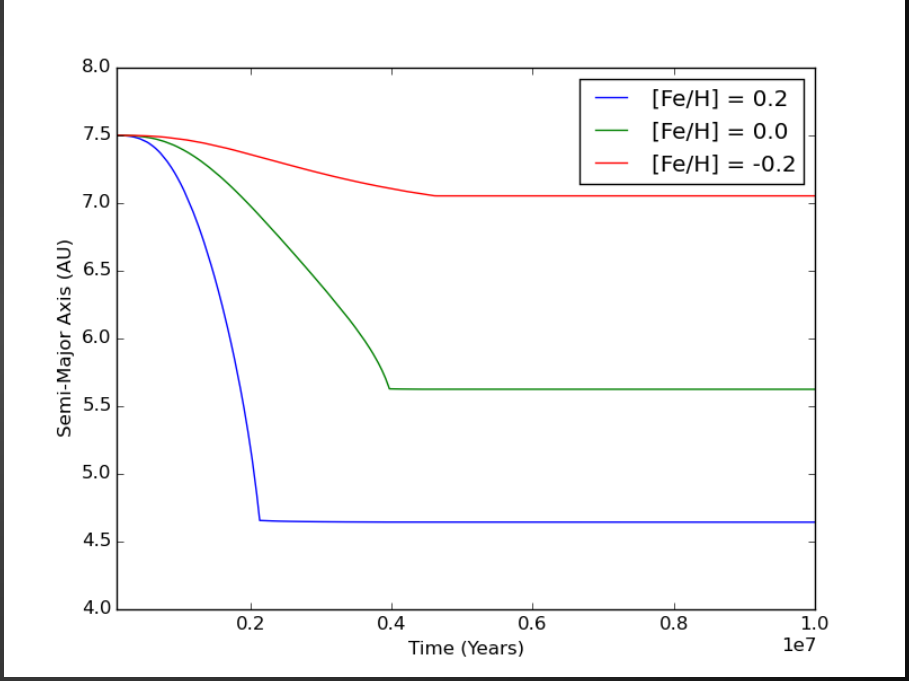
Metallicity Results: [Fe/H] = 1



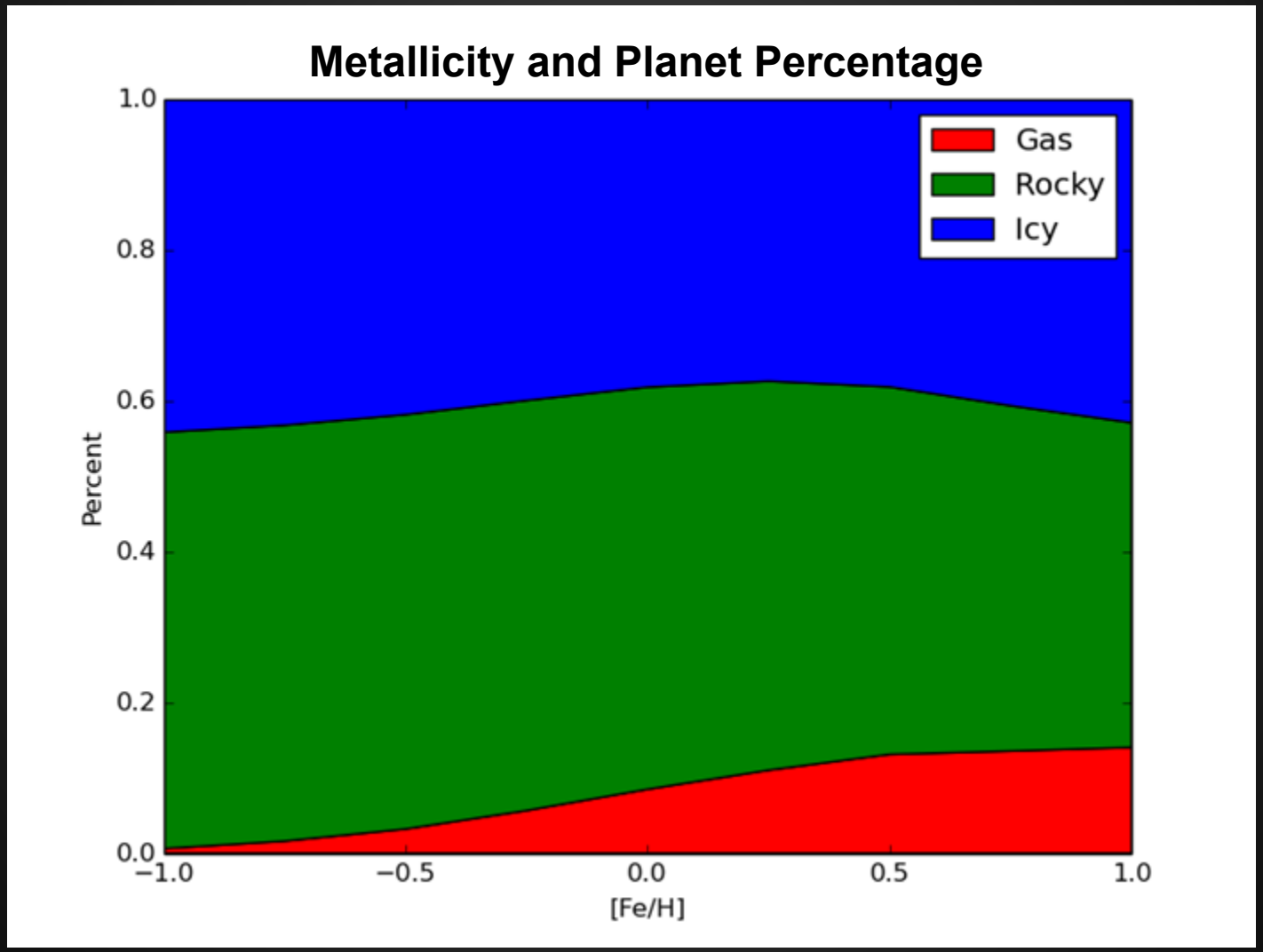


Controlled Study





Relative Populations



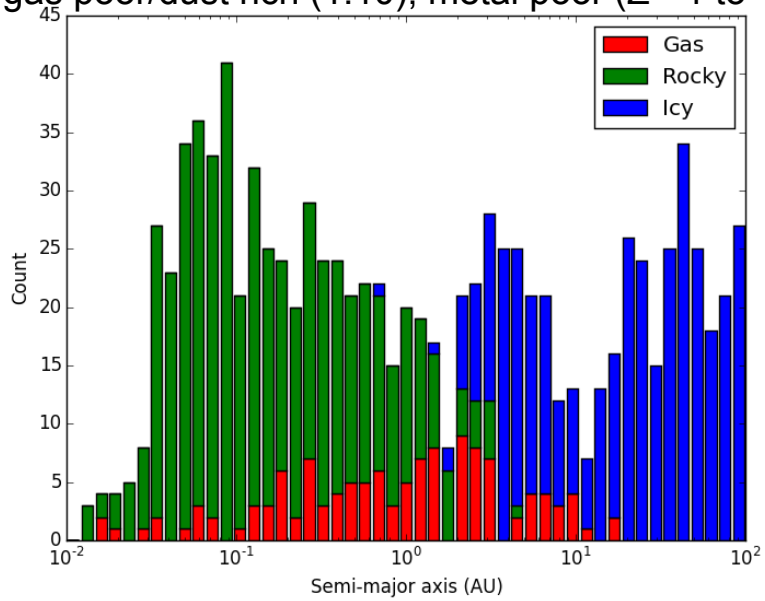
Results and Discussion

- Single planet evolution test cases
  - [Fe/H] = -0.2, 0, 0.2
  - Effects on migration properties in Type I/II
- Trends stepping through metallicity
  - [Fe/H]: -1.0 dex to +1.0 dex
  - Populations produced and locations
    - Gas planets: Scarce at low [Fe/H], migrate in w/increasing [Fe/H]
    - Icy planets: More higher mass planets w/increasing [Fe/H]
    - Rocky planets: Scarce at low [Fe/H]; at high [Fe/H], more can form into icy planets (ice line placement)
- Metallicity affects the following:
  - migration, relative populations of planets formed, opacity/temperature through disk, core/envelope properties...
- Varying dust-to-gas ratio (1:10, 1:500 vs nominal ~1:100) at constant metallicity produces similar populations to varying [Fe/H]

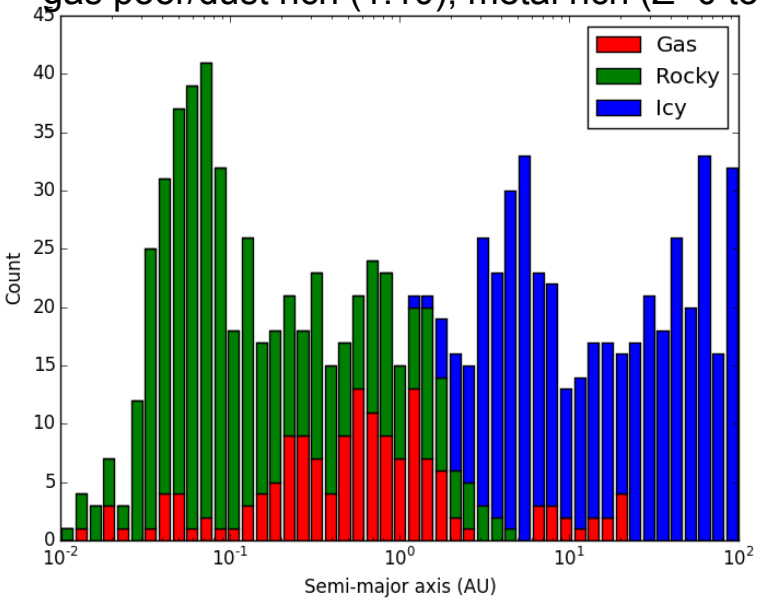
Additional Ideas

- What does it mean for us to observe in a simulated population that super-Earths correlate with metallicity?
- Higher order effects of dust-to-gas ratio varying through different disk regions
  - Observed differences in dust disk size and gas (CO) disk sizes

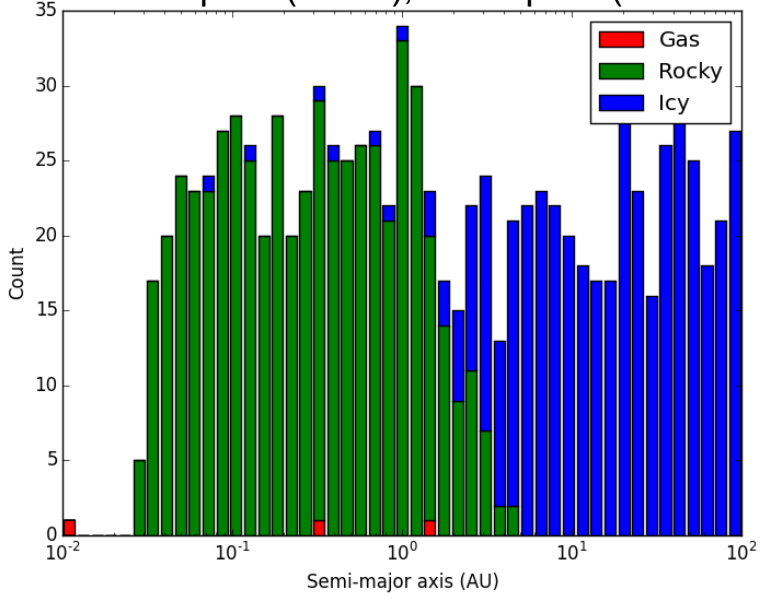
gas poor/dust rich (1:10), metal poor (Z=-1 to 1)



gas poor/dust rich (1:10), metal rich (Z=0 to 1)



gas rich/dust poor (1:500), metal poor (Z=-1 to 1)



gas rich/dust poor (1:500), metal rich (Z=0 to 1)