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: $[\text{Fe/H}] = -1$
Metallicity Results: $[\text{Fe/H}] = 0$
Metallicity Results: $[\text{Fe/H}] = 1$
Controlled Study
Relative Populations

Metallicity and Planet Percentage

- Gas
- Rocky
- Icy

Percent

[Fe/H]
Results and Discussion

- Single planet evolution test cases
  - $[\text{Fe/H}] = -0.2, 0, 0.2$
  - Effects on migration properties in Type I/II

- Trends stepping through metallicity
  - $[\text{Fe/H}]: -1.0 \text{ dex to } +1.0 \text{ dex}$
  - Populations produced and locations
    - Gas planets: Scarce at low $[\text{Fe/H}]$, migrate in w/increasing $[\text{Fe/H}]$
    - Icy planets: More higher mass planets w/increasing $[\text{Fe/H}]$
    - Rocky planets: Scarce at low $[\text{Fe/H}]$; at high $[\text{Fe/H}]$, 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 $[\text{Fe/H}]$
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 rich/dust poor (1:500), 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 rich (Z=0 to 1)