A planet population dichotomy from isotopic enrichment?

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Contact
timlichtenberg.net
tim.lichtenberg@phys.ethz.ch

Tim Lichtenberg (ETH Zürich)
Michael R. Meyer (ETH Zürich), Richard J. Parker (Liverpool JMU), Gregor J. Golabek (BGI Bayreuth), Taras V. Gerya (ETH Zürich)

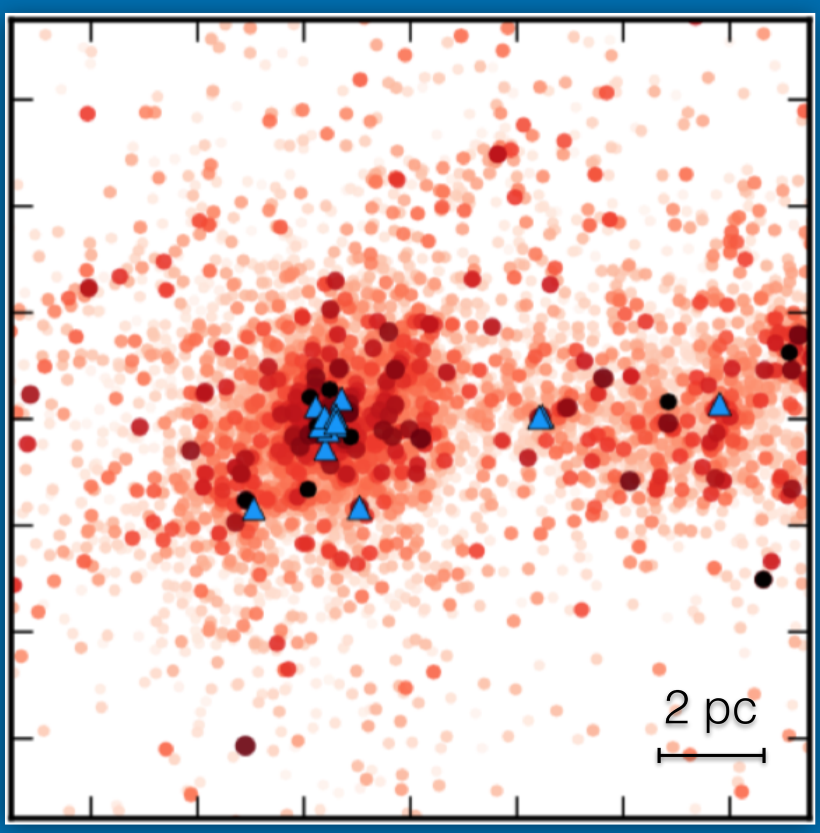


Fig. 1. Expanding stellar cluster with 10,000 stars after 5 Myr of evolution.

Motivation

- Short-lived radioisotopes (SLRs) were the primary heat source of planetesimals (<1000 km) in the early Solar System.
- Heat-up crucially affected thermo-mechanical history, interior structure and volatile inventory of planetesimals.
- Supernovae provide SLR source for natal planetary systems in young star clusters.
- We quantify SLR abundances and resulting volatile degassing on planetesimals before delivery to terrestrial planets.

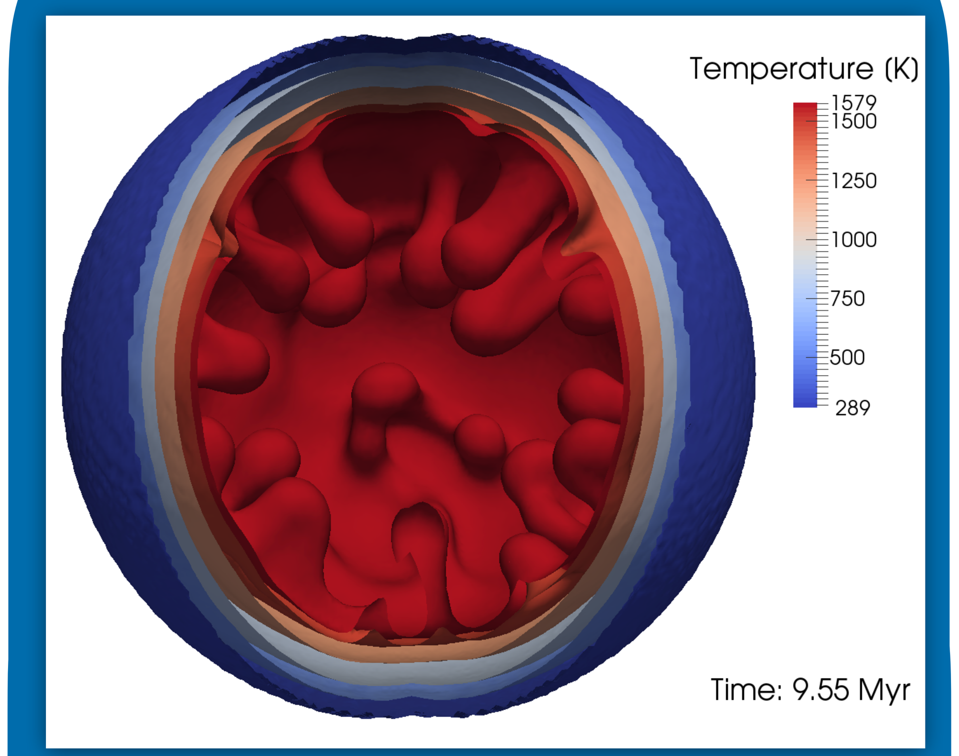


Fig. 3. Internally convecting planetesimal of 110 km in radius.

Isotopic disk enrichment from supernova pollution

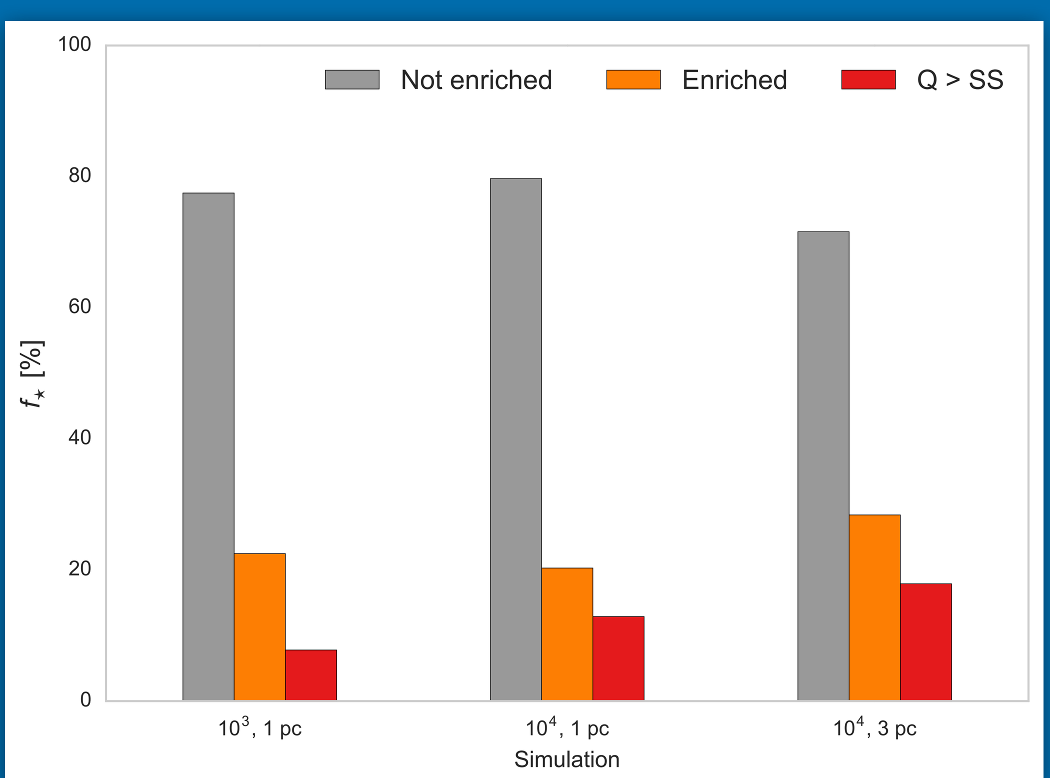
Lichtenberg T, Parker RJ, Meyer MR. Isotopic enrichment of forming planetary systems from supernova pollution. Submitted.

Supernova (SN) pollution mechanism

- SLRs fused in massive stars
- SN ejecta deliver material to nearby circumstellar disks of low-mass stars

Methods

- N-body simulations of 10^3—10^4 stellar clusters.
- SLR yields from SN ejecta
- Viscous accretion disk models
- Ejecta-disk cross-section capture



Findings

- SLR distribution dichotomy
- 10-30 % of disks enriched, many excessively (> Solar System levels)
- Majority of systems with zero SLR abundances

Fig. 2. Histogram of predicted distribution dichotomy.

Planetesimal interior evolution due to radiogenic heating

Lichtenberg T, Golabek GJ, Gerya TV, Meyer MR (2016). The effects of short-lived radionuclides and porosity on the early thermo-mechanical evolution of planetesimals. Icarus, 274, 350-365.

Systematic study of planetesimal thermo-mechanical evolution

- 2D/3D fluid dynamic models, silicate rheology (EOS)
- Parameter space:
  - formation time t_{form}
  - radius R_P
  - macro porosity Φ_{init}

Findings

- 3 regimes: solid, melt, mixing
- R_P and t_{form} dominant
- Φ_{init} only significant effects for small bodies
- Pure melt regime: t ~ 1-1.5 Myr (transition regime)

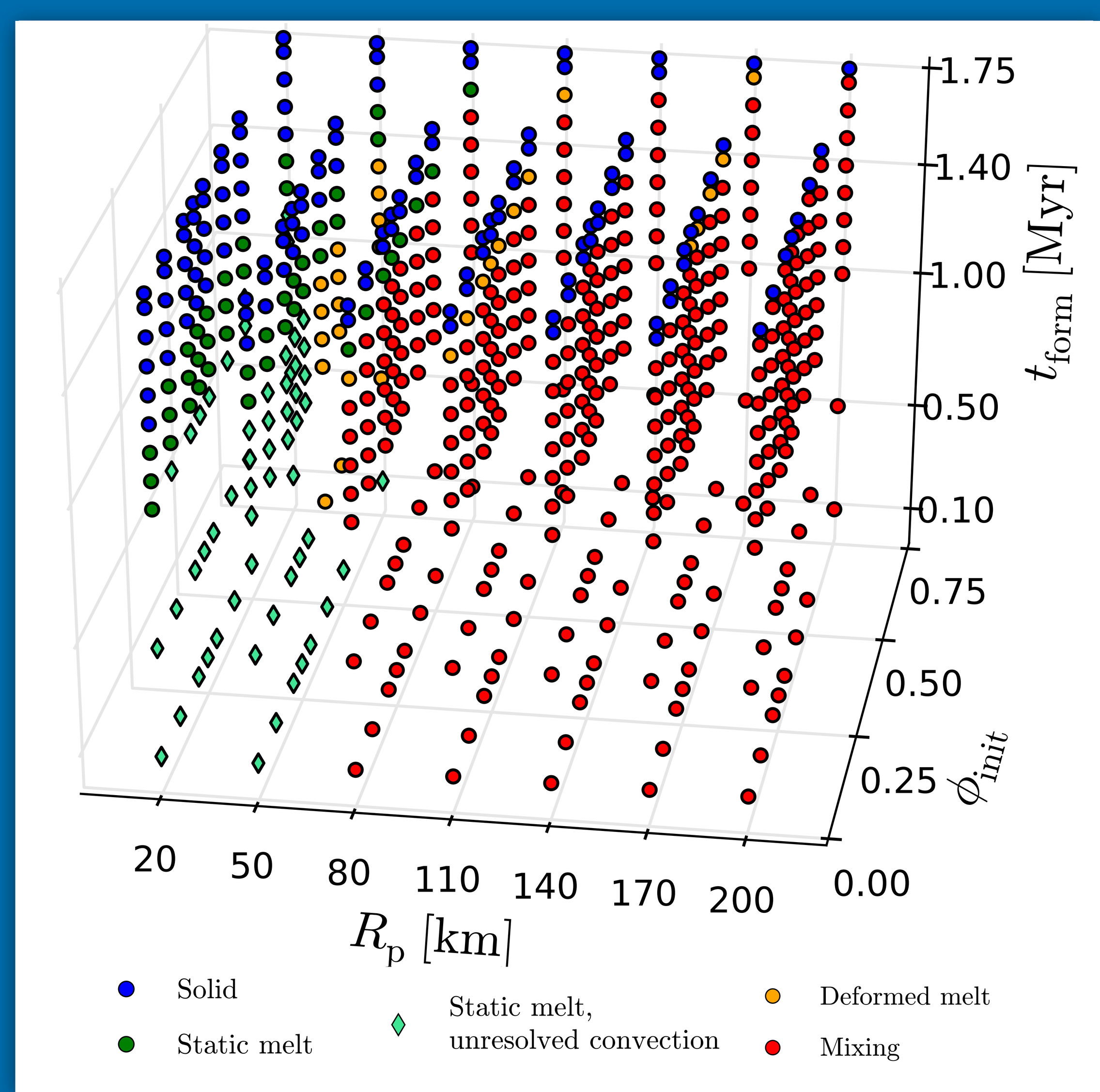
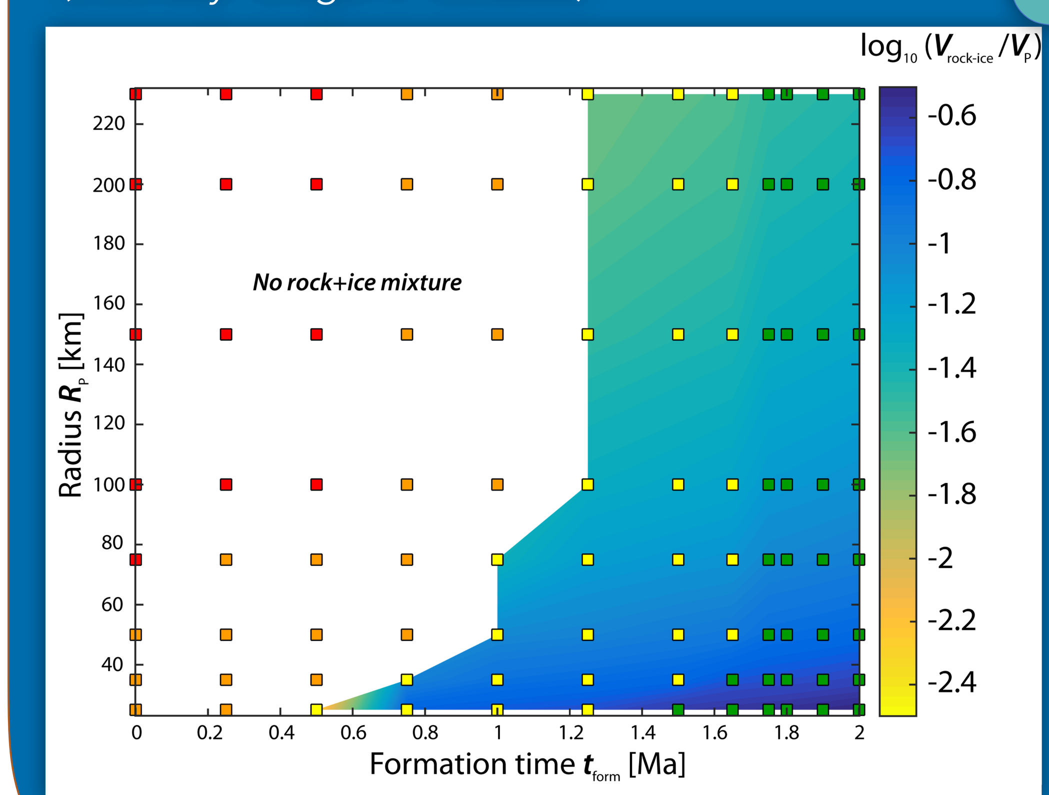


Fig. 4. 2D thermo-mechanical planetesimal regimes.

Volatile exsolution prior to delivery?

SLR-rich = water-poor planets vs. SLR-poor = water-rich planets

Fig. 5a. Retained rock+ice mixture in radiogenically heated planetesimals. (Courtesy: Gregor J. Golabek)



Study outlook and preliminary results

- ➡ Qualitative degassing regimes, transition regime most critical
- ➡ Fig. 1 & 2 using fluid model from study above

In preparation — 2-phase fluid calculations of water degassing

- ➡ How does **melt transport** redistribute the heat source radially (and perhaps laterally)?
- ➡ How does the total **retention of water** and its radial structure depend on the relative timing of planetesimal formation and cessation of ^{26}Al activity?

Fig. 5b. Retained hydrous silicates in radiogenically heated planetesimals. (Courtesy: Gregor J. Golabek)