Heating of planetesimals from ^{60}Fe & ^{26}Al

Hunting the source of short-lived radioisotopes and simulating desiccation in planetesimals

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Contents & questions

What are SLRs?

How do they end up in protoplanetary disks?

How do they affect planet formation?

What causes SLR enrichment?

How do disks survive this enrichment?

[1] Fu & Elkins-Tanton 2014

What are SLRs?

Short-lived radioisotopes

- Half-lives on the order of 1 Myr.
- ^{26}Al and ^{60}Fe primarily discussed.
- Primary heating source in the early solar system **[1]**.
- Homogenous throughout solar system.
- Wolf-Rayet (WR) winds and supernovae are sources of SLRs.

[1] Fu & Elkins-Tanton 2014

Planetesimal desiccation

- Heating = vaporisation and outgassing [1].
- Desiccation & formation of water-poor planets.
- Heating source for stratification.

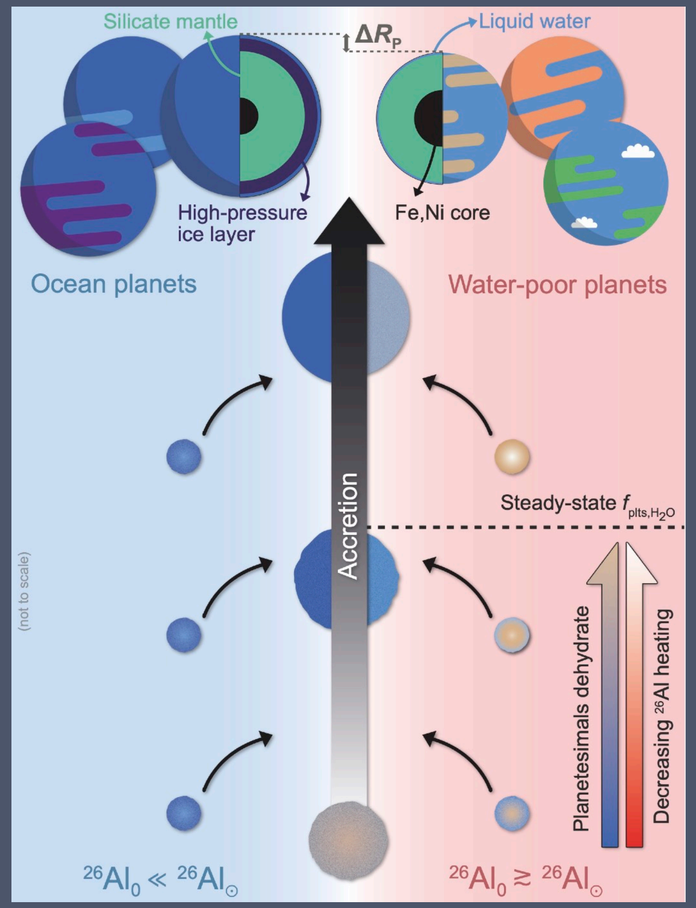


Fig. Lichtenberg+ 2019, [1] Lichtenberg+ 2019

Planetesimal heating by SLRs

Motivations

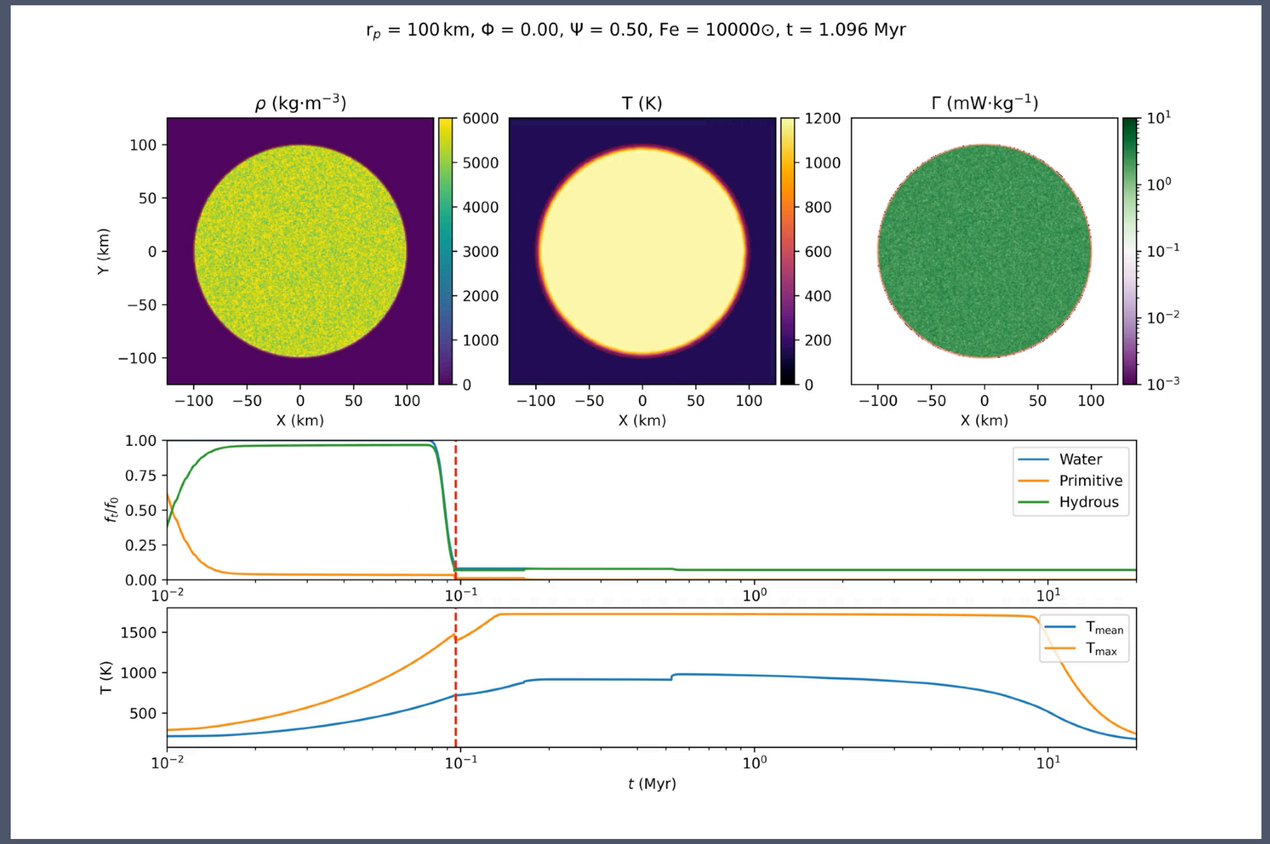
How much does the SLR ^{60}Fe influence heating and desiccation?

How much ^{60}Fe needed to get desiccation?

Melting rocks

Eatson, Parker, Lichtenberg & Gerya 2024

- Simulations using I2ELVIS **[1]**.
- Parameter space explored varying enrichment and Fe content.
- Measuring water retention fraction.

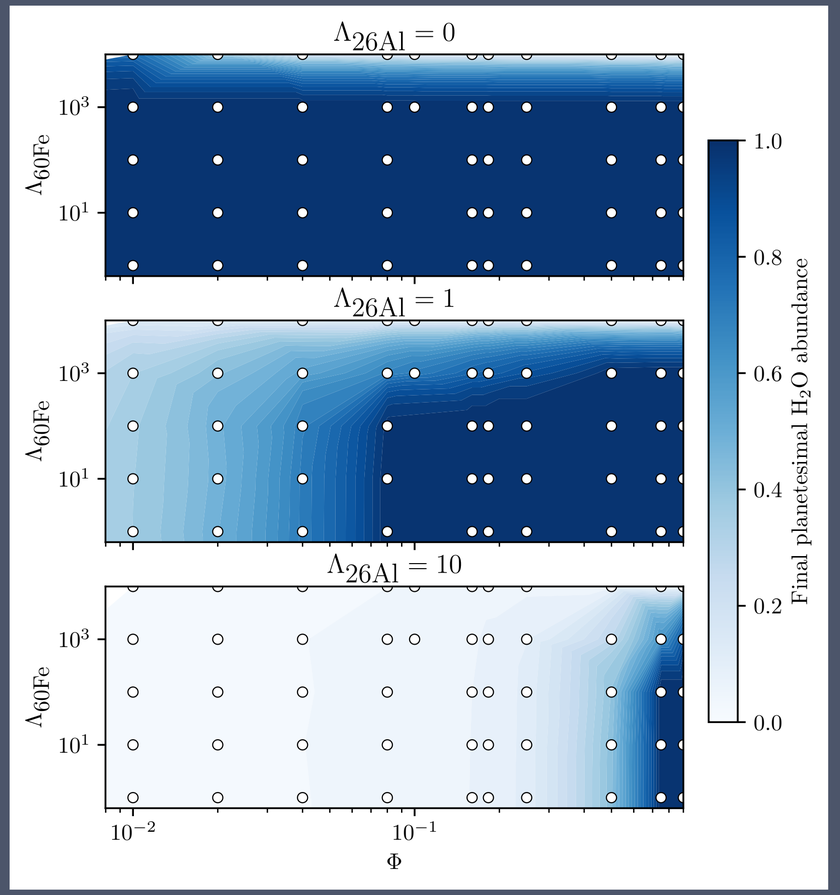


[1] Gerya (2019), github.com/FormingWorlds/i2elvis_planet

Drying out rocks

Eatson, Parker, Lichtenberg & Gerya 2024

- ^{60}Fe ~200x solar for any desiccation!
- 1/10th solar needed for ^{26}Al equivalent **[1]**.
- ^{26}Al a far more effective SLR for heating & desiccation.



[1] Lichtenberg+ 2019

SLR enrichment of disks

More motivations

How common are highly enriched ^{26}Al and ^{60}Fe disks?

How dependent is enrichment on star forming region density?

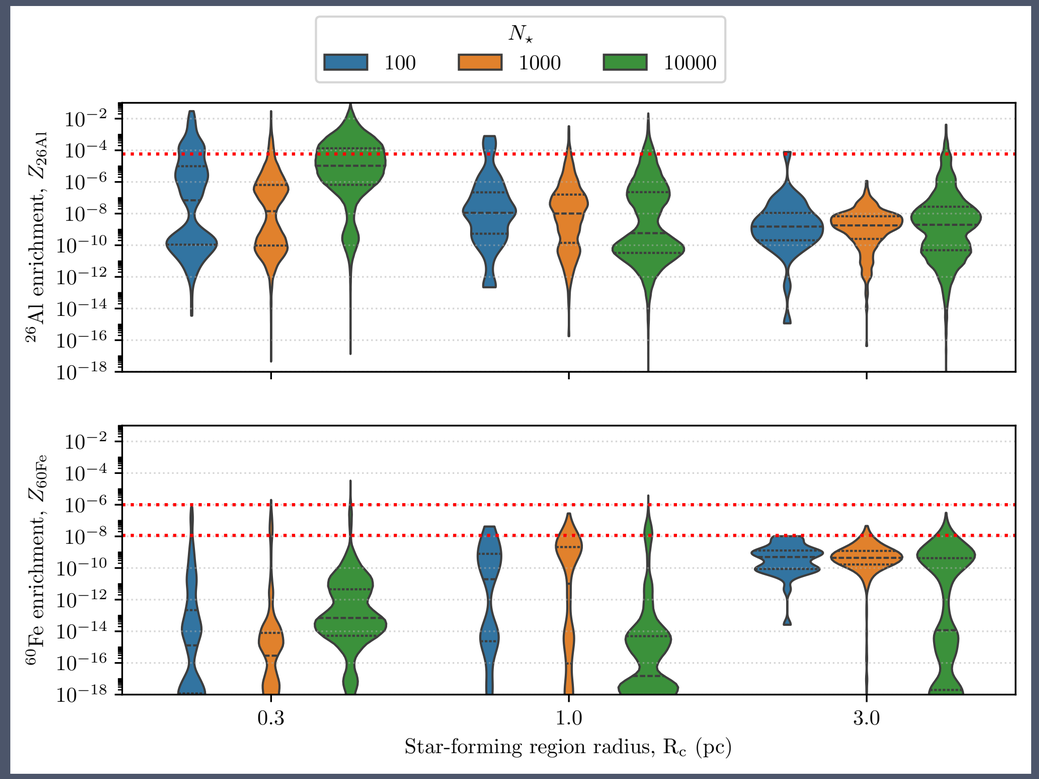
Are disks enriched through SNe or early-type stellar winds?

Is there another pre-formation mechanism?

Enriching disks

Eatson, Parker & Lichtenberg 2024

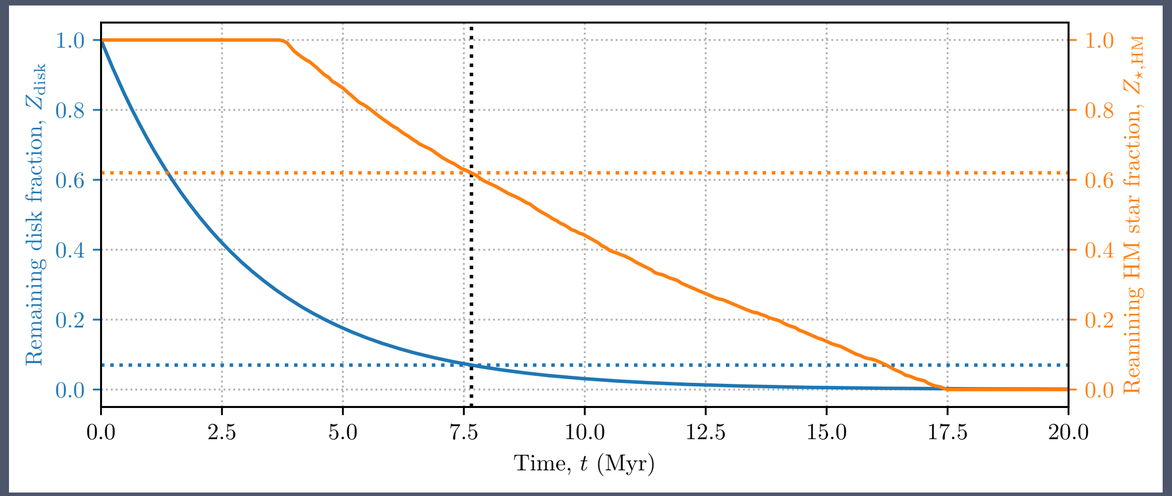
- AMUSE **[1]** library used to combined N-body and stellar evolution codes.
- Enrichment dependent on cluster density.
- ^{26}Al enrichment above solar system levels somewhat common.
- ^{60}Fe enrichment is less pronounced.



[1] Portegies Zwart & McMillan (2018)

The hitch with winds and SNe

- ^{60}Fe not produced by WR winds **[1]**.
- Less available disks when supernovae occur (“islands of explodability”).
- Photoevaporation and shocks **[2]**.
- Other enrichment methods?



X-axis: time
Y-axis left/blue: Remaining disks
Y-axis right/orange: Remaining high-mass stars

[1] Limongi & Chieffi 2018 [2] Patel+ 2023

Interlopers?

- AGB star observed to pass through cluster **[1]**.
- AGBIs inject ^{26}Al *and* ^{60}Fe.
- Gentler winds, less UV flux.

[1] Parker & Schoettler, 2023

AGBI sensitivity to...

Interloper evolution?

Encounter velocity?

Interlopers!

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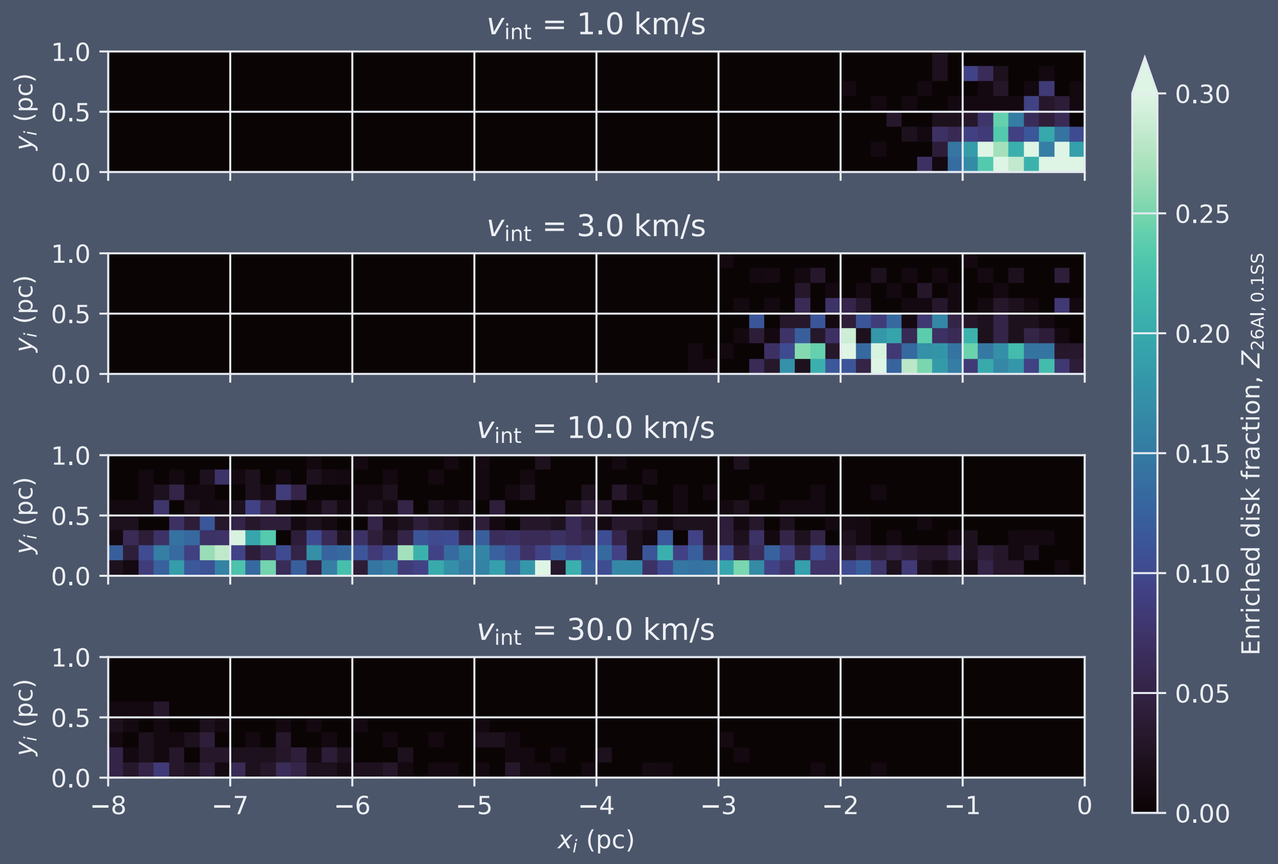
In prep.
QR code for poster!

- ~30% of disks well enriched in best case.
- “Near misses” still enrich.
- Good ^{60}Fe enrichment too!
- Faster AGBIs still enrich.



Interlopers!

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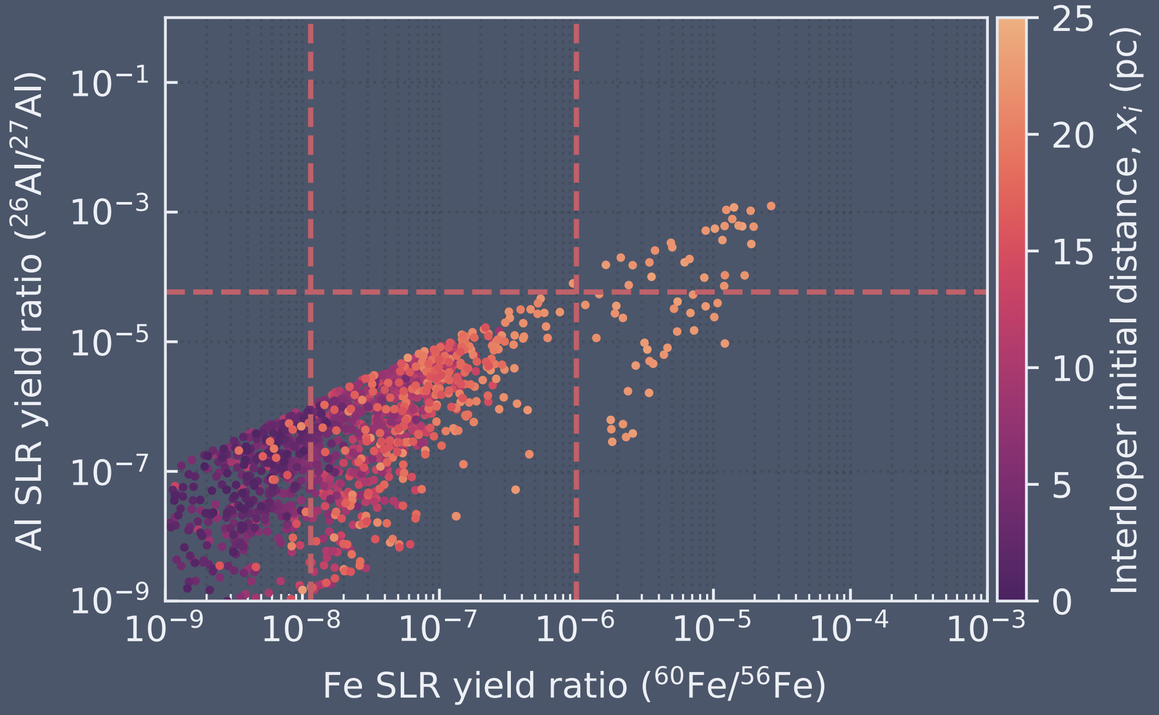
- ~30% of disks well enriched in best case.
- “Near misses” still enrich.
- Good ^{60}Fe enrichment too!
- Faster AGBIs still enrich.
- High enrichment even at 30 km/s.



Probably gone on too long

Wrap it up!

Conclusions

- Decay heat from SLRs in disks causes desiccation of planetesimals.
- Decay heating mainly through ^{26}Al, sims show ^{60}Fe needs high enrichment. ^{60}Fe a useful tracer for formation mechanism.
- *N*-body sims show that massive star ^{60}Fe enrichment is not sufficient for this level of enrichment.
- Enrichment through AGB interlopers provides an alternate, gentler route to disk enrichment for ^{26}Al and ^{60}Fe.

Questions?

⇦ *Slide deck and poster here!*

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