

# Heating of planetesimals from $^{60}\text{Fe}$ & $^{26}\text{Al}$

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



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# Contents & questions

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*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?*

# What are SLRs?

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# Short-lived radioisotopes

- Half-lives on the order of 1 Myr.
- $^{26}\text{Al}$  and  $^{60}\text{Fe}$  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.

# Planetesimal desiccation

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

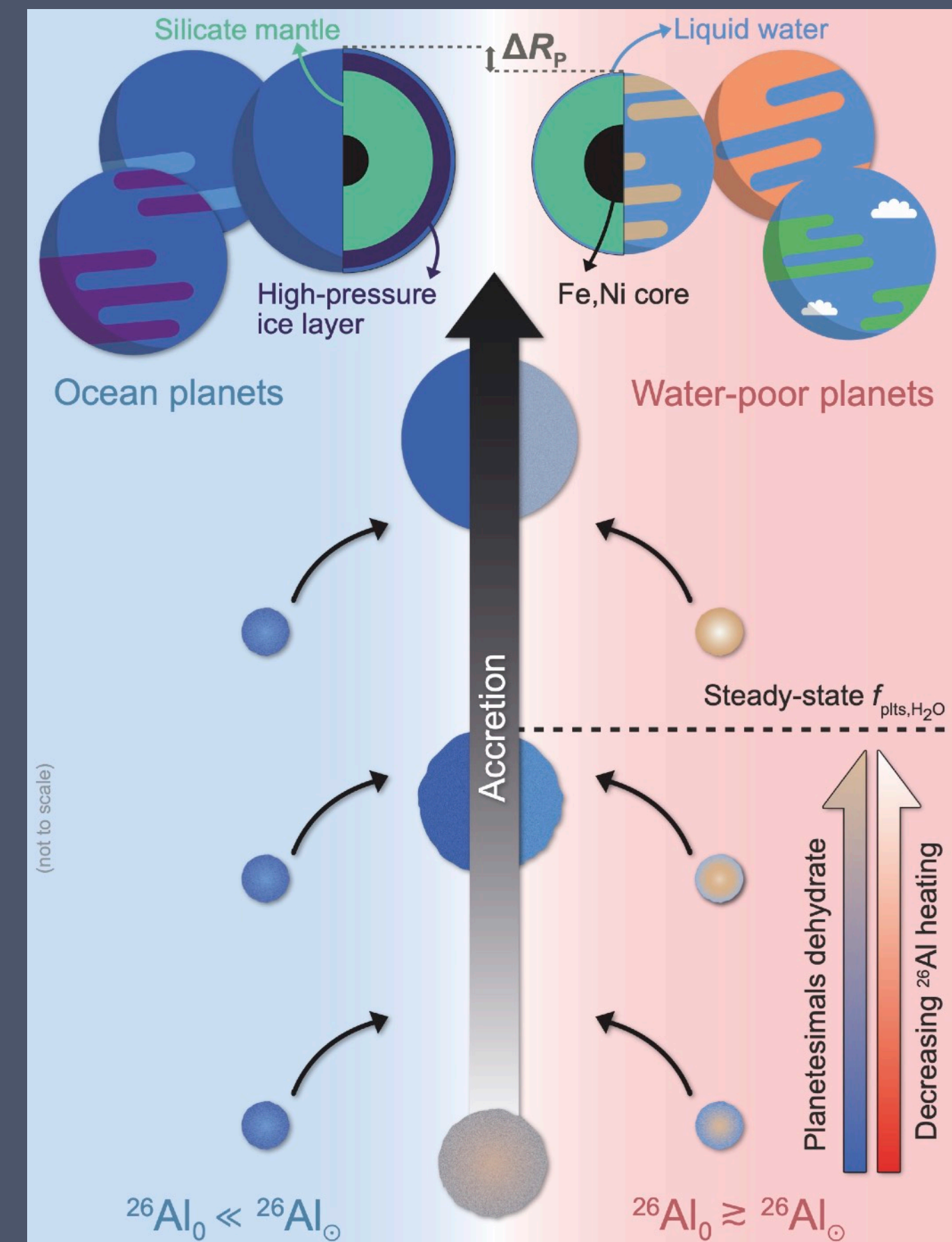


Fig. Lichtenberg+ 2019, [1] Lichtenberg+ 2019

# Planetesimal heating by SLRs

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# Motivations

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*How much does the SLR  $^{60}\text{Fe}$  influence heating and desiccation?*

*How much  $^{60}\text{Fe}$  needed to get desiccation?*

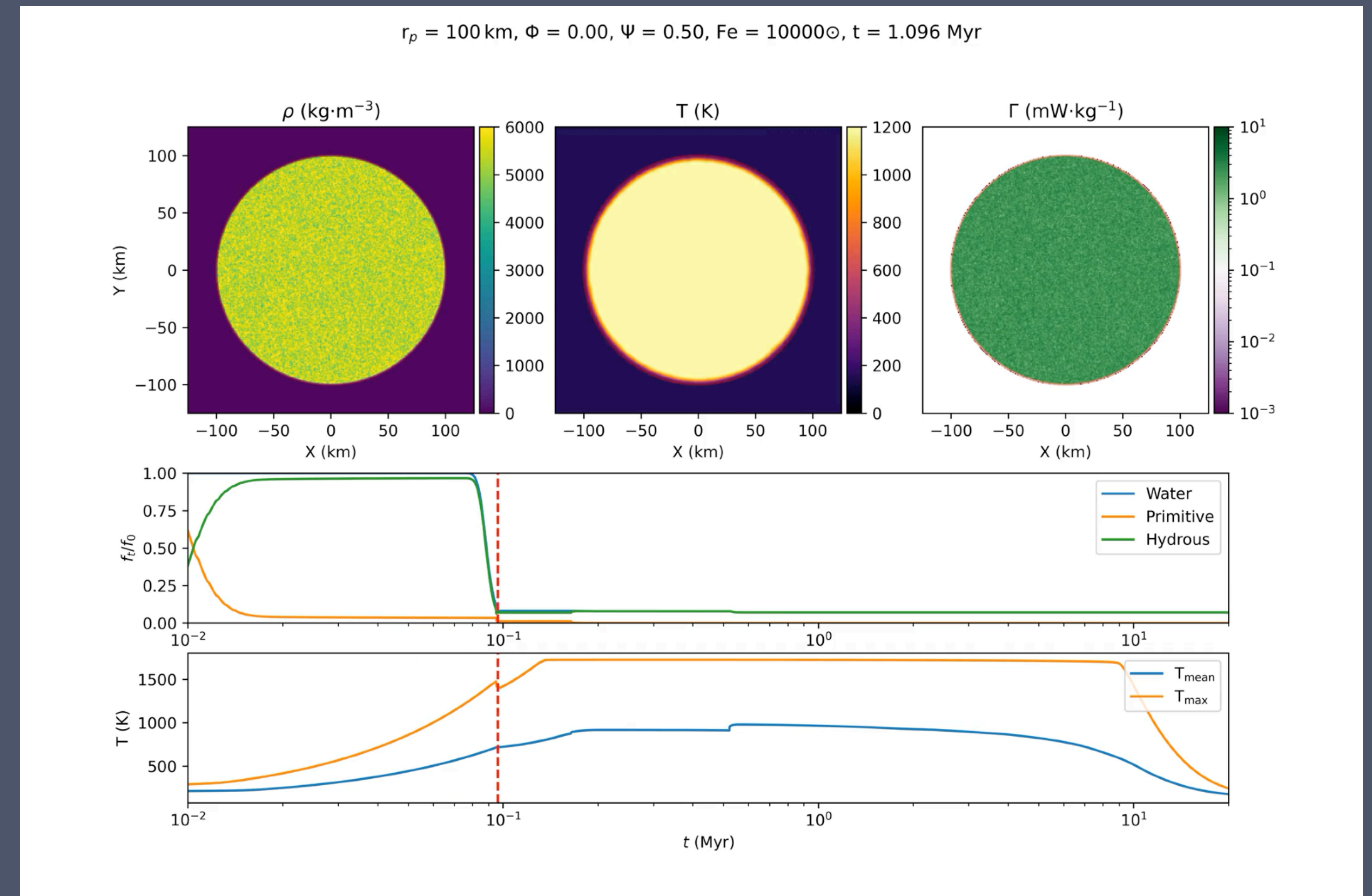
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# Melting rocks

*Eatson, Parker,  
Lichtenberg & Gerya  
2024*



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

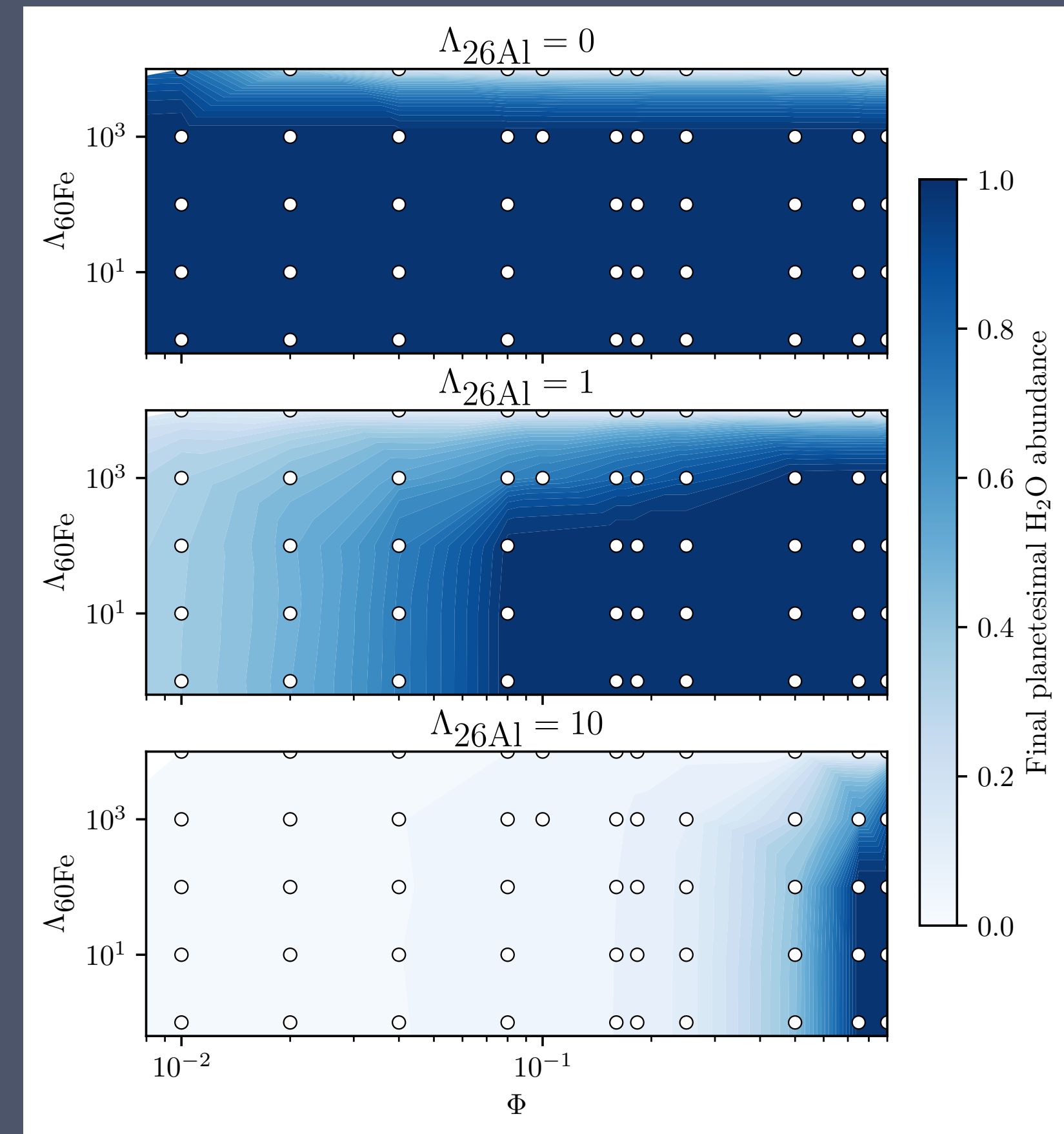


# Drying out rocks

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



# SLR enrichment of disks

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# More motivations

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*How common are highly enriched  $^{26}\text{Al}$  and  $^{60}\text{Fe}$  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?*

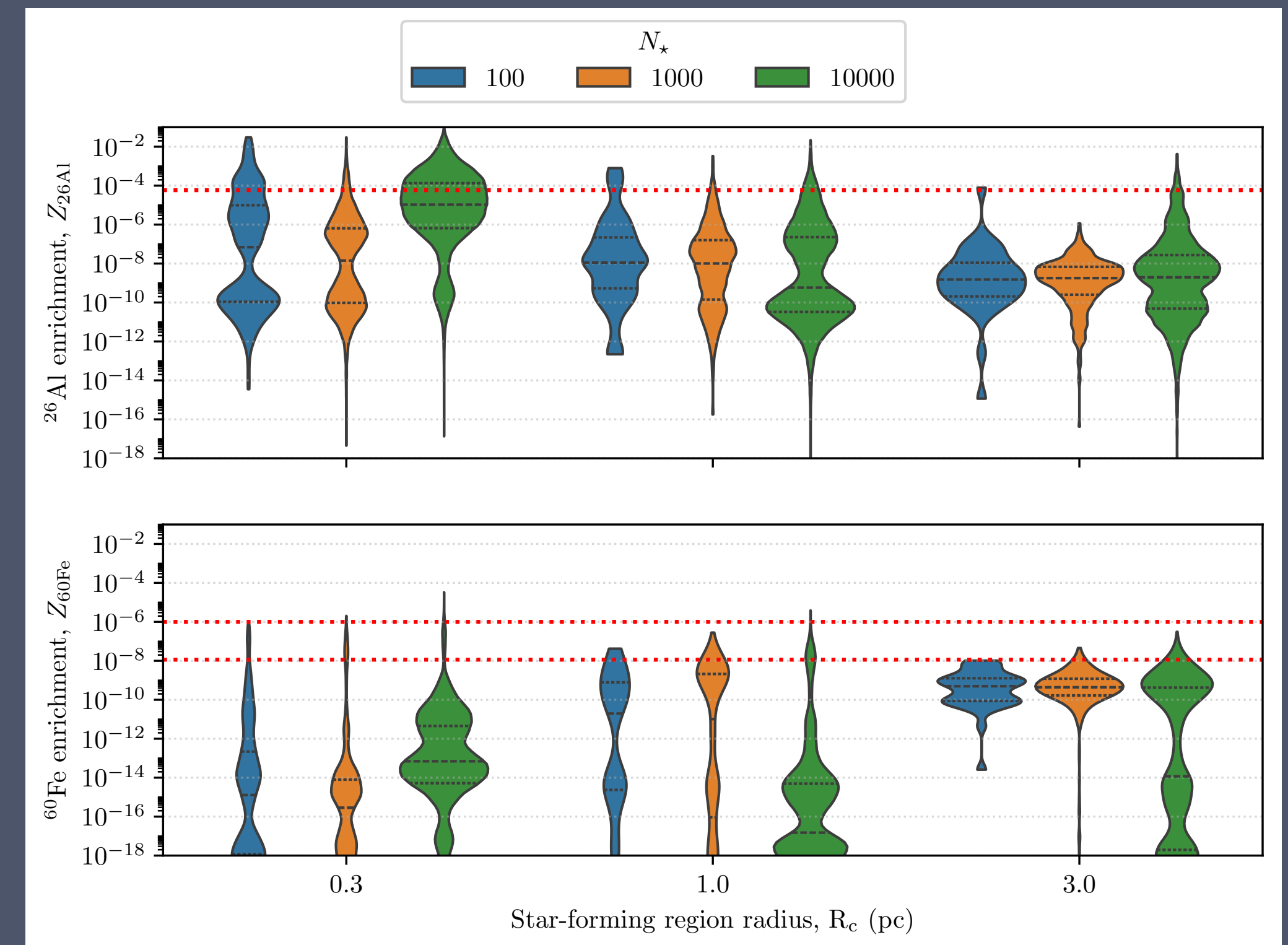
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# Enriching disks

*Eatson, Parker &  
Lichtenberg 2024*

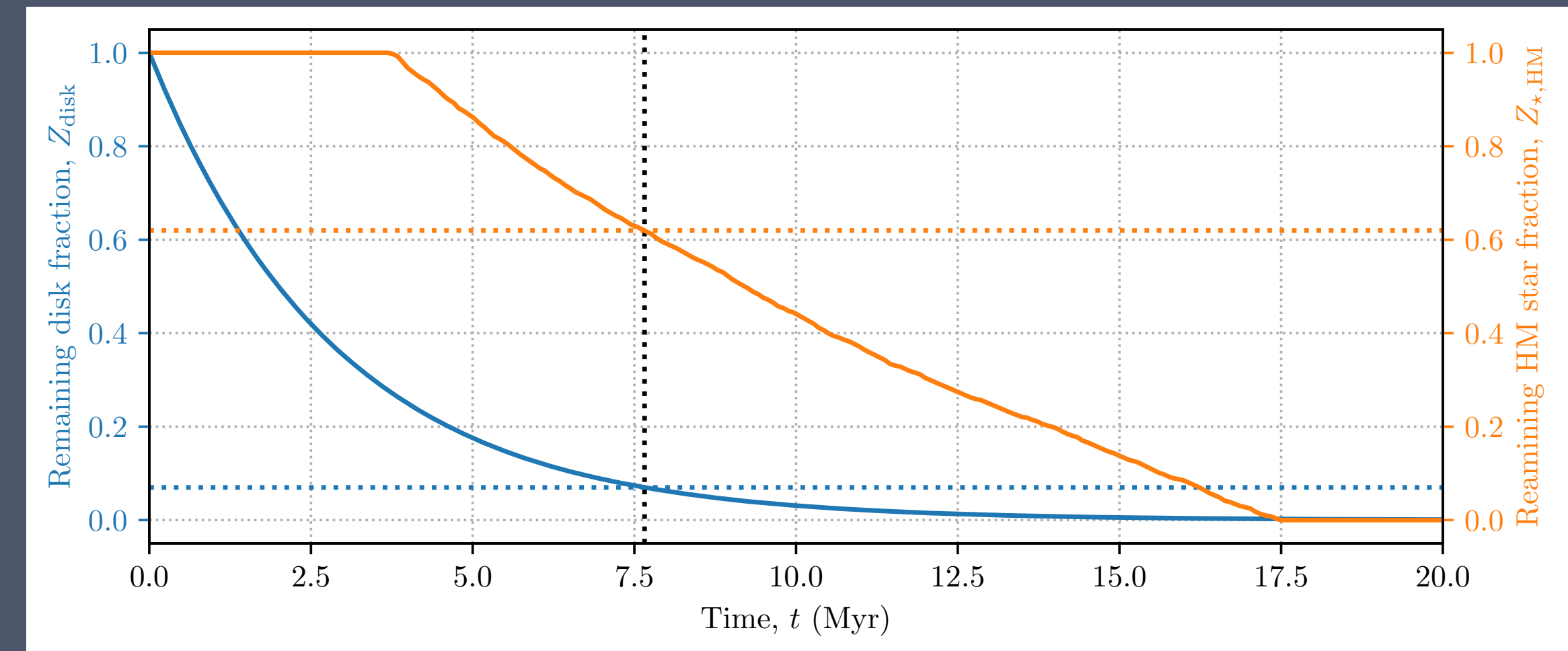


- AMUSE [1] library used to combined N-body and stellar evolution codes.
- Enrichment dependent on cluster density.
- $^{26}\text{Al}$  enrichment above solar system levels somewhat common.
- $^{60}\text{Fe}$  enrichment is less pronounced.



# The hitch with winds and SNe

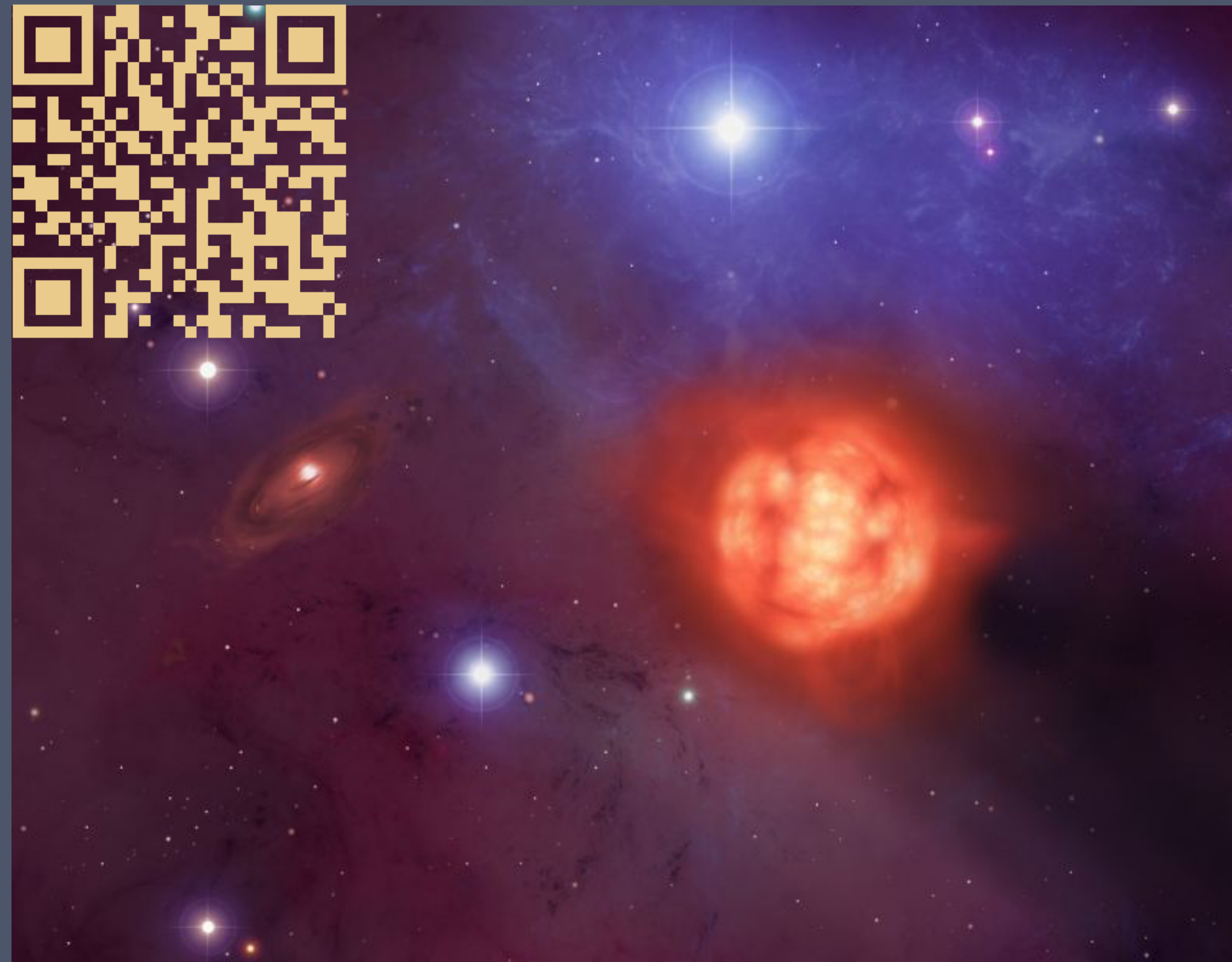
- $^{60}\text{Fe}$  not produced by WR winds [1].
- Less available disks when supernovae occur (“islands of explodability”).
- Photoevaporation and shocks [2].
- Other enrichment methods?



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

# Interlopers?

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



# AGBI sensitivity to...

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*Interloper evolution?*

*Encounter velocity?*

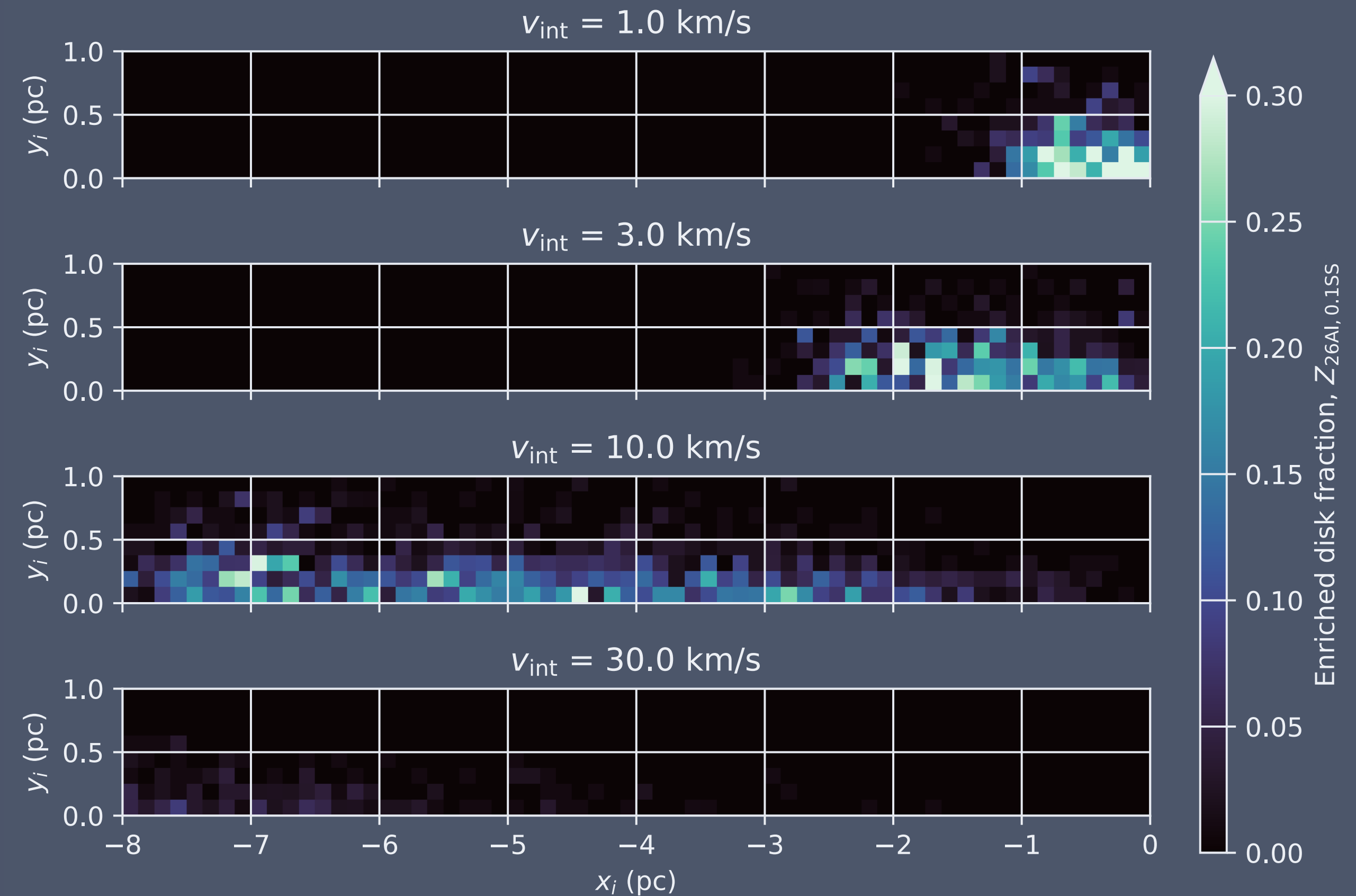
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# Interlopers!

*Eatson & Parker  
In prep.  
QR code for poster!*



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

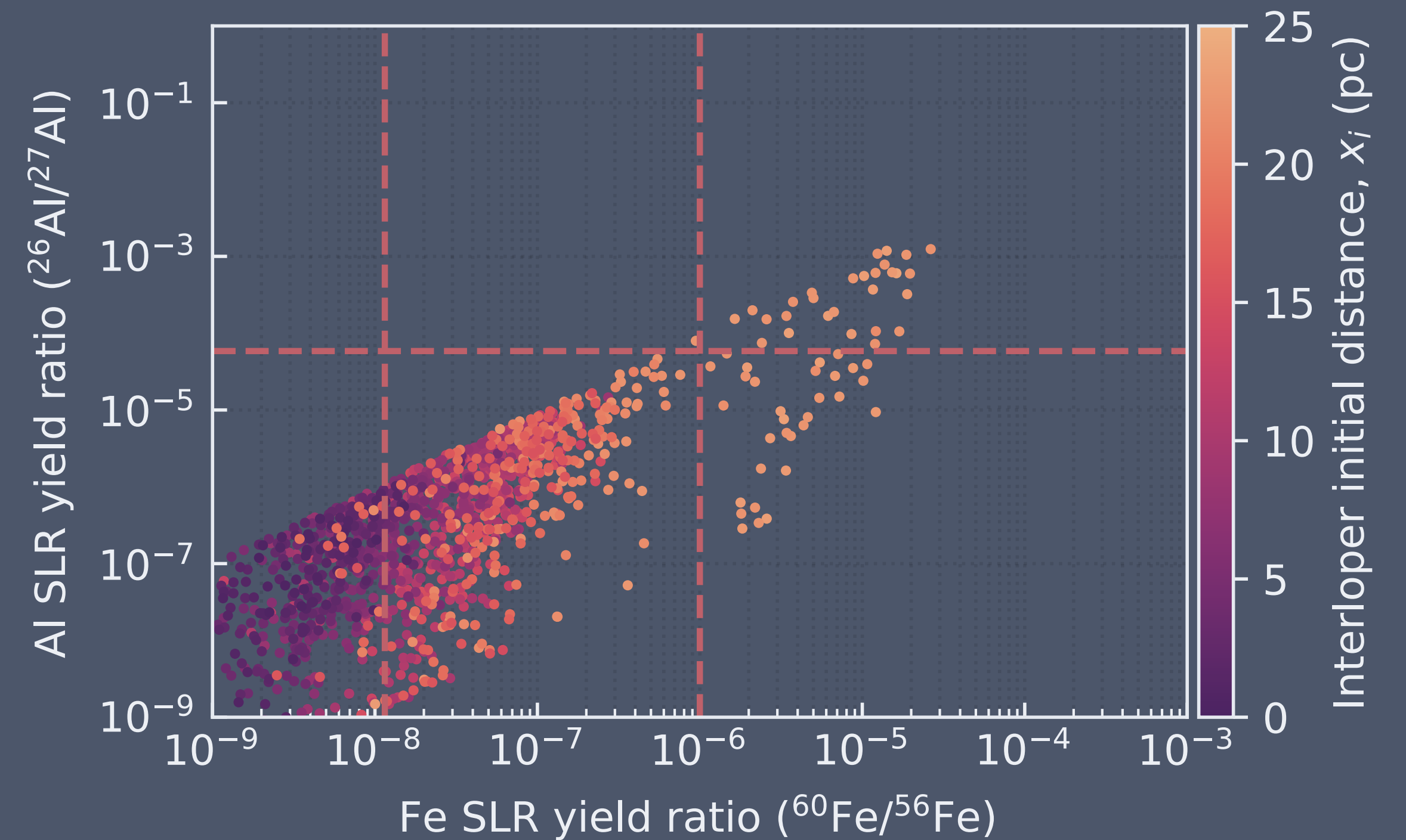


# Interlopers!

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- ~30% of disks well enriched in best case.
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- Good  $^{60}\text{Fe}$  enrichment too!
- Faster AGBs still enrich.
- High enrichment even at 30 km/s.



Probably gone on too  
long

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*Wrap it up!*

# Conclusions

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