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Cr isotope systematics of martian meteorites Implications for the early differentiation history of Mars

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Cr isotope systematics of martian meteorites

Implications for the early differentiation history of Mars

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Processes and timescales of martian mantle differentiation remain enigmatic

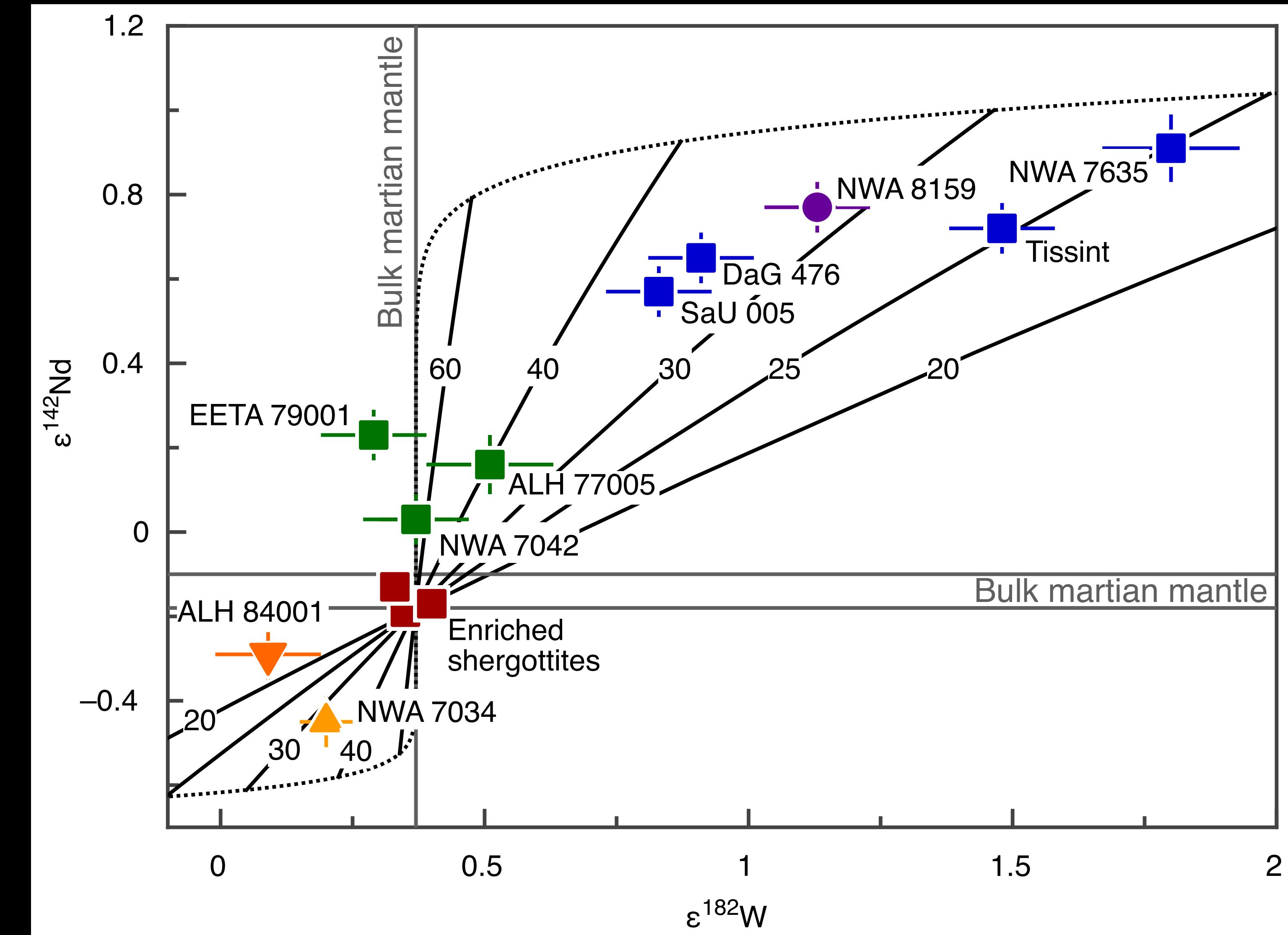
Sm-Nd chronometry: ‘Late’ differentiation at ~60 Ma
Hf-W chronometry: ‘Early’ differentiation at 20-30 Ma

Global (e.g. magma ocean) or more localized differentiation processes?

$\epsilon^{142}\text{Nd}$ vs. $\epsilon^{182}\text{W}$ data of martian meteorites

Isotopic
heterogeneities
preserved over ~ 4.5
billion years

Was the martian
mantle ever
homogeneous?



Questions and approach

When did large-scale differentiation of the martian mantle commence?

Was the martian mantle ever isotopically homogeneous?

Here we address these questions using Cr isotopes

Cr isotope systematics of martian meteorites



Mn/Cr fractionation during:

- volatility related processes
- core formation
- silicate differentiation

^{54}Cr is a nucleosynthetic tracer

Cr isotope systematics of martian meteorites

$^{53}\text{Mn} \rightarrow ^{53}\text{Cr}$ ($t_{1/2} = 3.7$ Ma)

Finding ^{53}Cr variations on Mars would provide evidence for differentiation within <20 Ma

occur during silicate fractionation

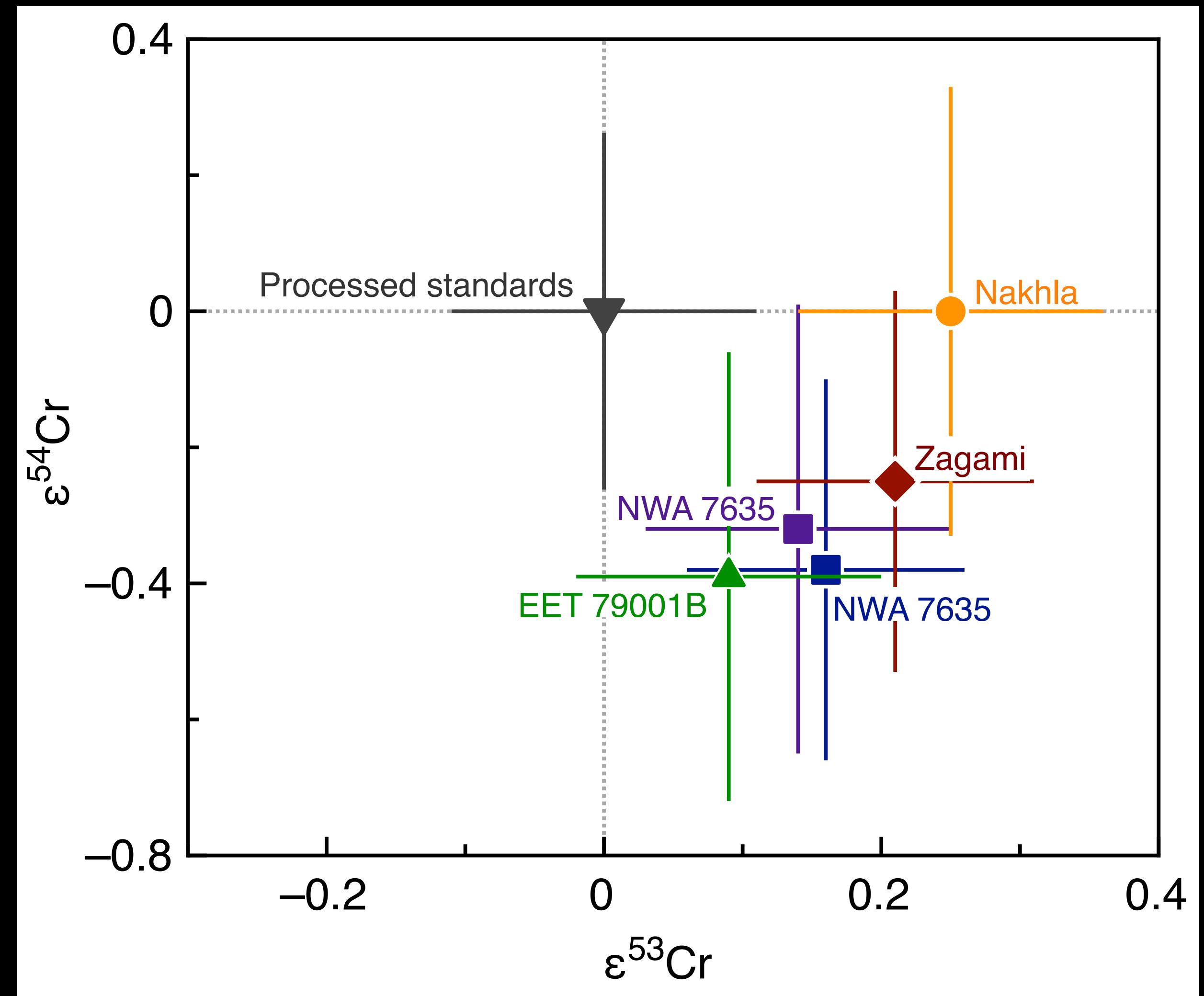
Samples and analytical methods

- ▶ Shergottites (1 enriched, 1 intermediate, 2 depleted), Nakhla
- ▶ Cr separated by ion exchange chromatography
- ▶ $^{53}\text{Cr}/^{52}\text{Cr}$ and $^{54}\text{Cr}/^{52}\text{Cr}$ analyzed on Triton TIMS at LLNL
- ▶ Fractionation correction by normalizing to $^{50}\text{Cr}/^{52}\text{Cr} = 0.00518$
- ▶ Precision: ~0.1 ϵ -units on $^{53}\text{Cr}/^{52}\text{Cr}$; ~0.3 ϵ -units on $^{54}\text{Cr}/^{52}\text{Cr}$

Results: $\varepsilon^{54}\text{Cr}$ vs. $\varepsilon^{53}\text{Cr}$ of martian meteorites

Uniform excess in $\varepsilon^{53}\text{Cr}$
of $+0.17 \pm 0.04$ (95% conf.)

Shergottites have uniform
deficit in $\varepsilon^{54}\text{Cr}$ of *ca.* -0.30



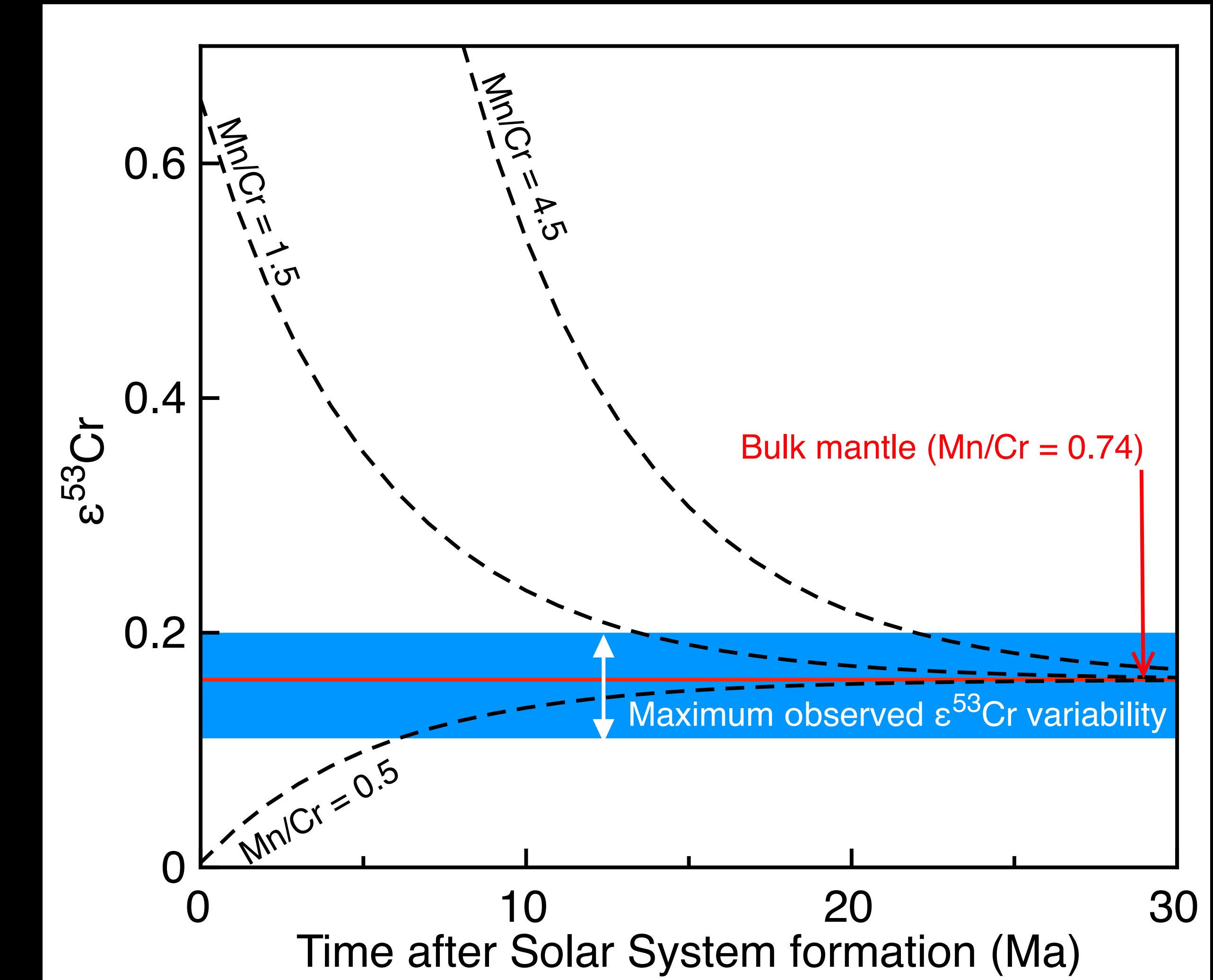
No ^{53}Cr heterogeneity within the martian mantle

1. Mn/Cr variations in martian mantle too small?
2. Martian mantle differentiation occurred after extinction of ^{53}Mn ?

No ^{53}Cr heterogeneity within the martian mantle

Martian mantle differentiation likely occurred >15 Ma after CAIs

Consistent with both Sm-Nd and Hf-W chronometry



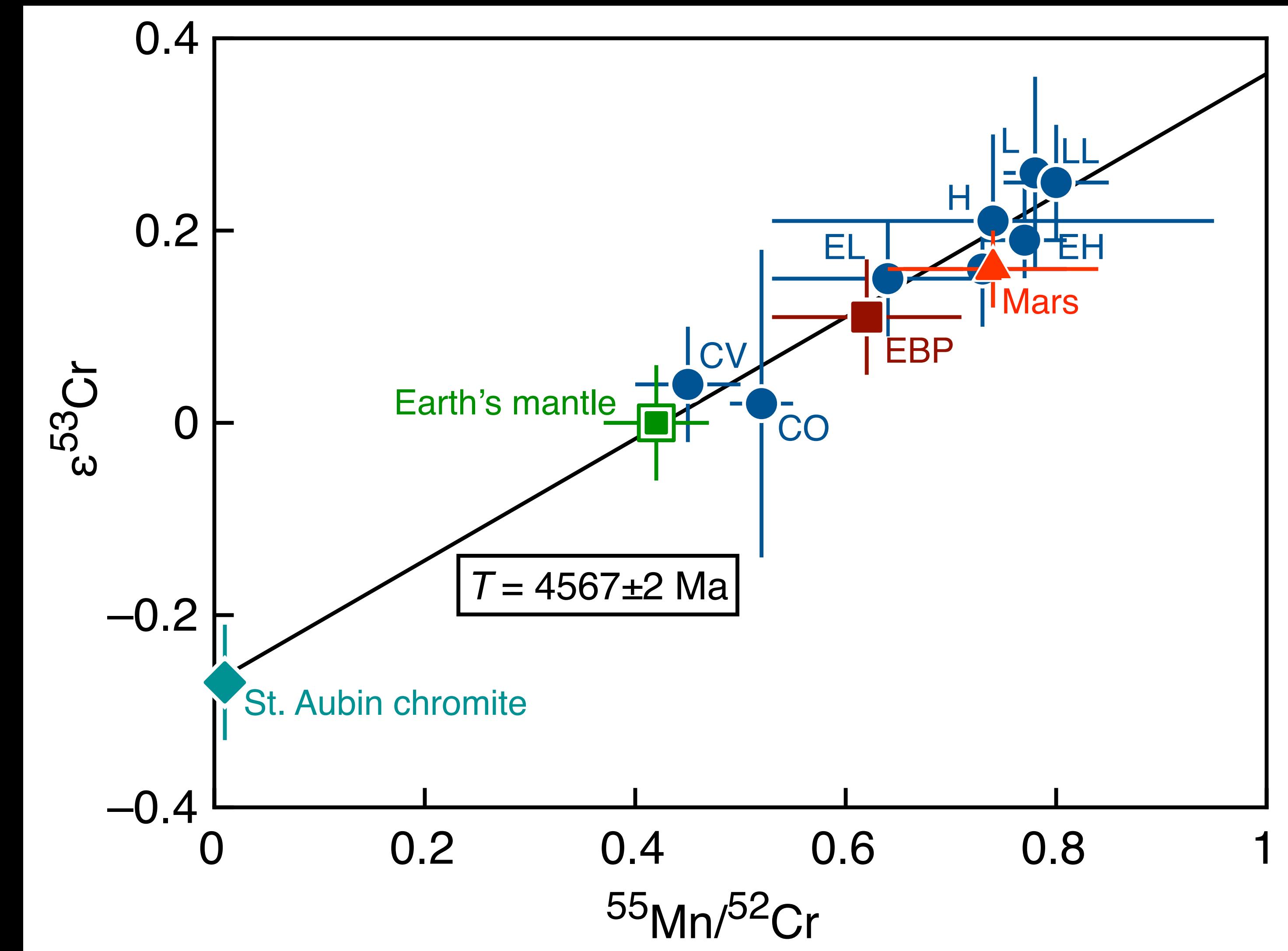
Origin of ^{53}Cr excess in martian meteorites

1. Mn/Cr fractionation during core formation?
2. Volatility induced Mn/Cr fractionation?

Origin of ^{53}Cr excess in martian meteorites

Mars plots on bulk
Mn-Cr isochron

Volatility induced
Mn/Cr fractionation
at ~ 4567 Ma



Data sources: This study and Trinquier et al. (2008); Qin et al. (2010); Palme & O'Neill (2014)

Conclusions

- ▶ No ^{53}Cr heterogeneities among martian meteorites
- ▶ Consistent with both Sm-Nd and Hf-W chronometry
- ▶ Mars has small excess in $\epsilon^{53}\text{Cr}$ relative to Earth
- ▶ Reflects inner solar system wide volatiliy induced Mn/Cr fractionation at *ca.* 4567 Ma
- ▶ Do ^{54}Cr heterogeneities exist on Mars?

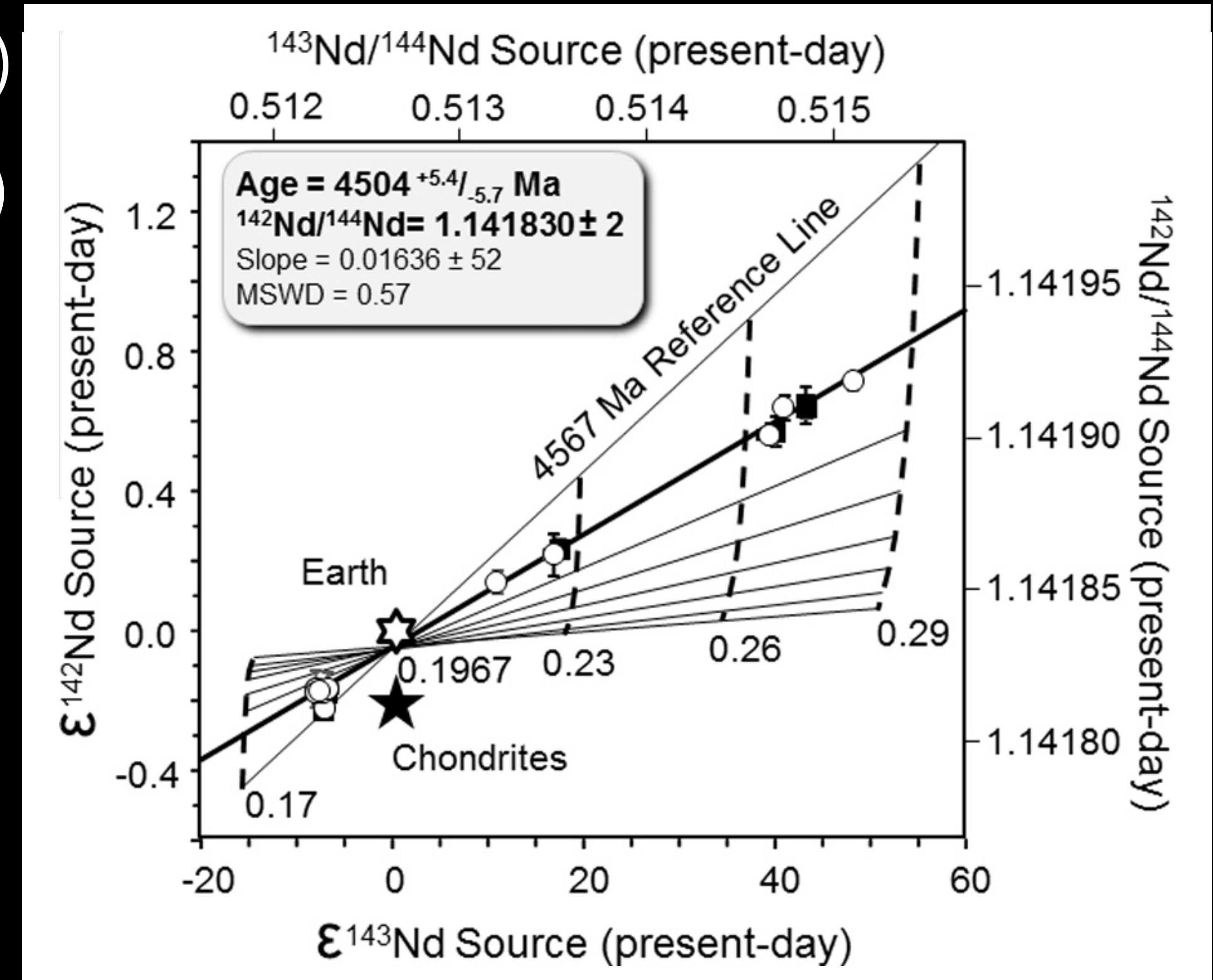
Sm-Nd chronometry of martian meteorites

$$^{146}\text{Sm} \rightarrow ^{142}\text{Nd} \quad (t_{1/2} \approx 103 \text{ Ma})$$

$$^{147}\text{Sm} \rightarrow ^{143}\text{Nd} \quad (t_{1/2} \approx 106 \text{ Ga})$$

Sm/Nd fractionation during silicate differentiation

Sm-Nd isochron age: ~60 Ma after CAIs

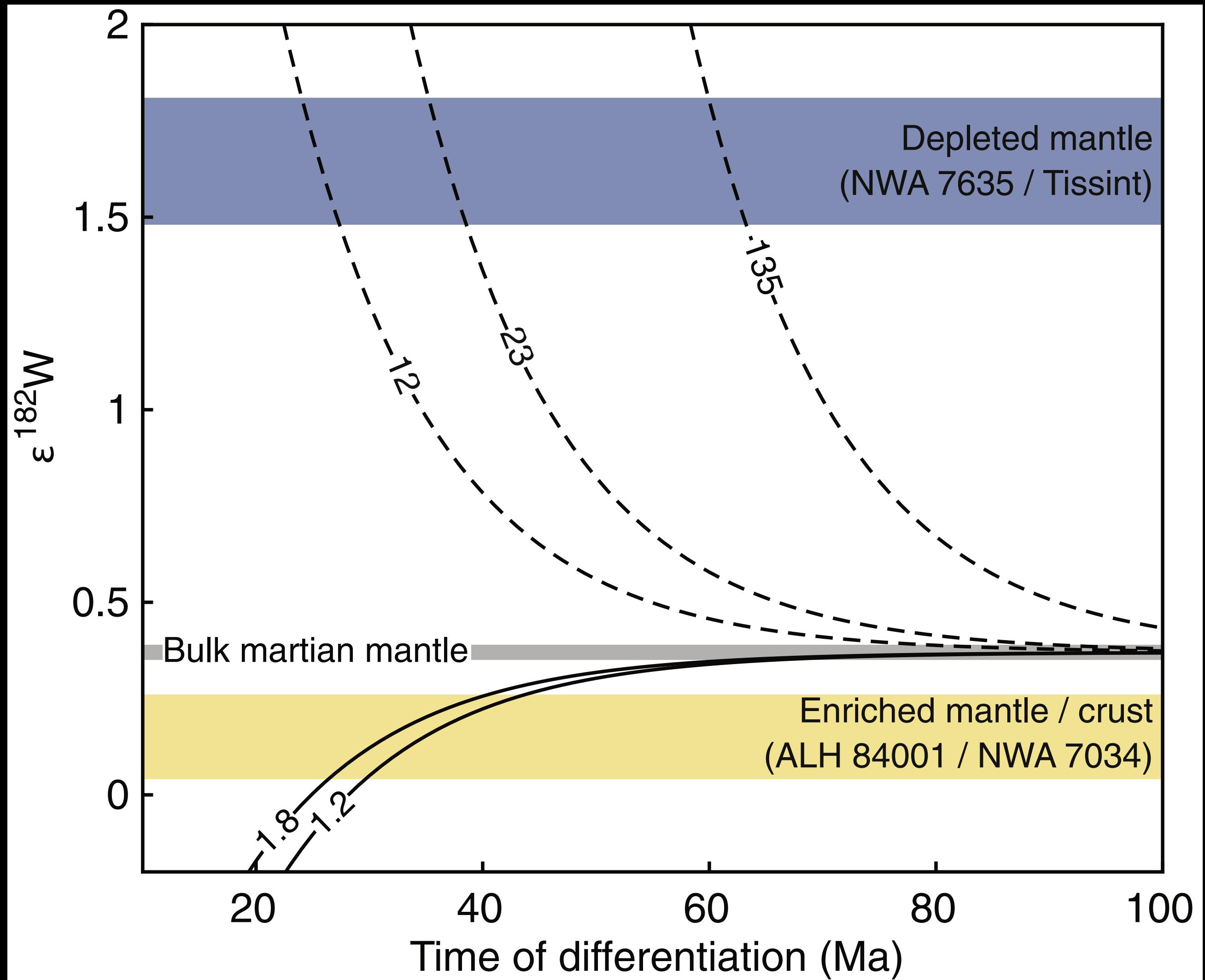


Hf-W chronometry of martian meteorites

$^{182}\text{Hf} \rightarrow ^{182}\text{W}$ ($t_{1/2} \approx 9 \text{ Ma}$)

Hf/W fractionation during silicate differentiation

Large ^{182}W variations require differentiation at **~20–30 Ma after CAIs**



^{54}Cr heterogeneity on Mars?

