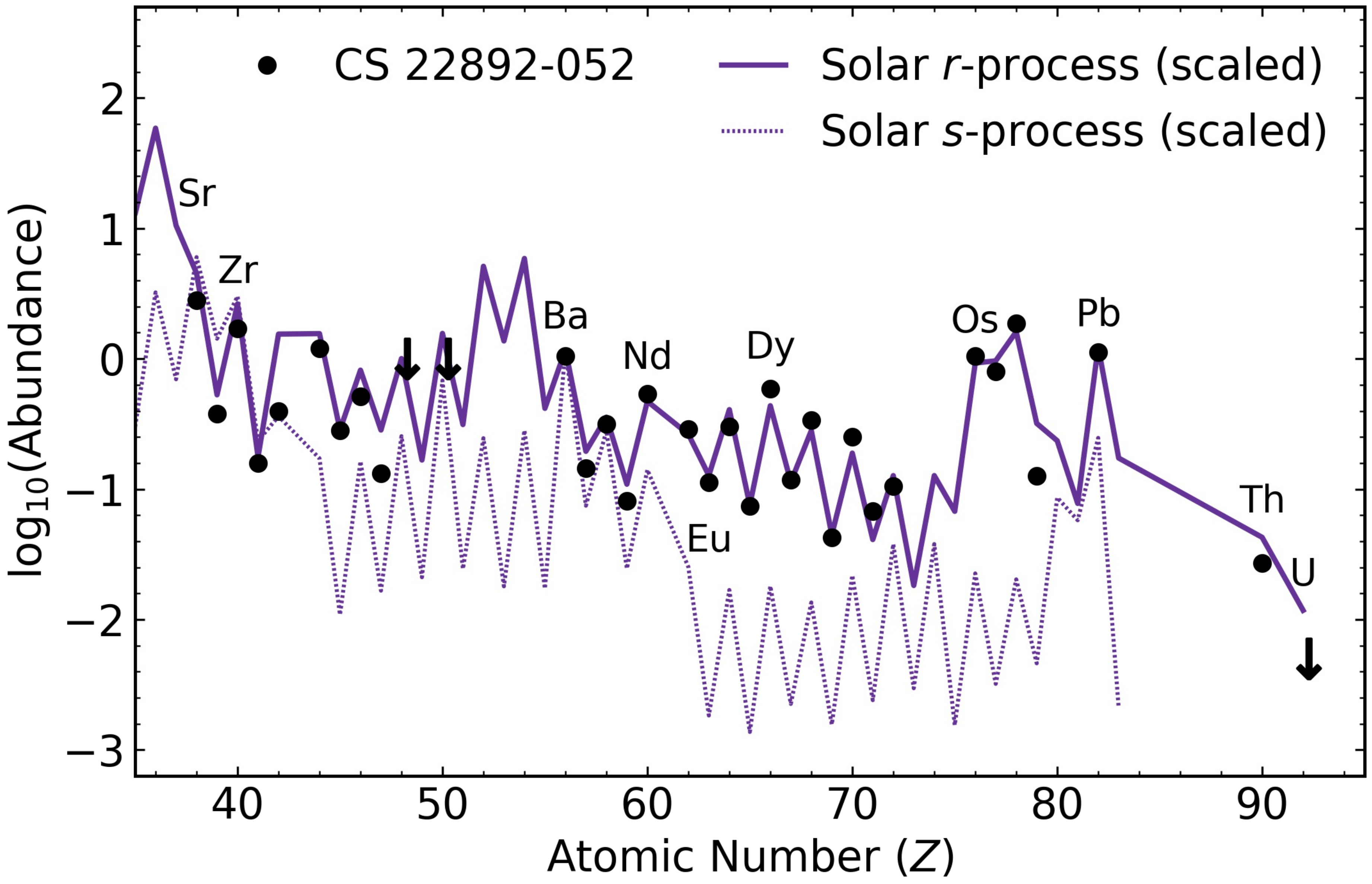
Actinide-Boost Stars may not Suggest a Separate r-Process Site

Erika M. Holmbeck

28 March 2019

r-process enhanced stars

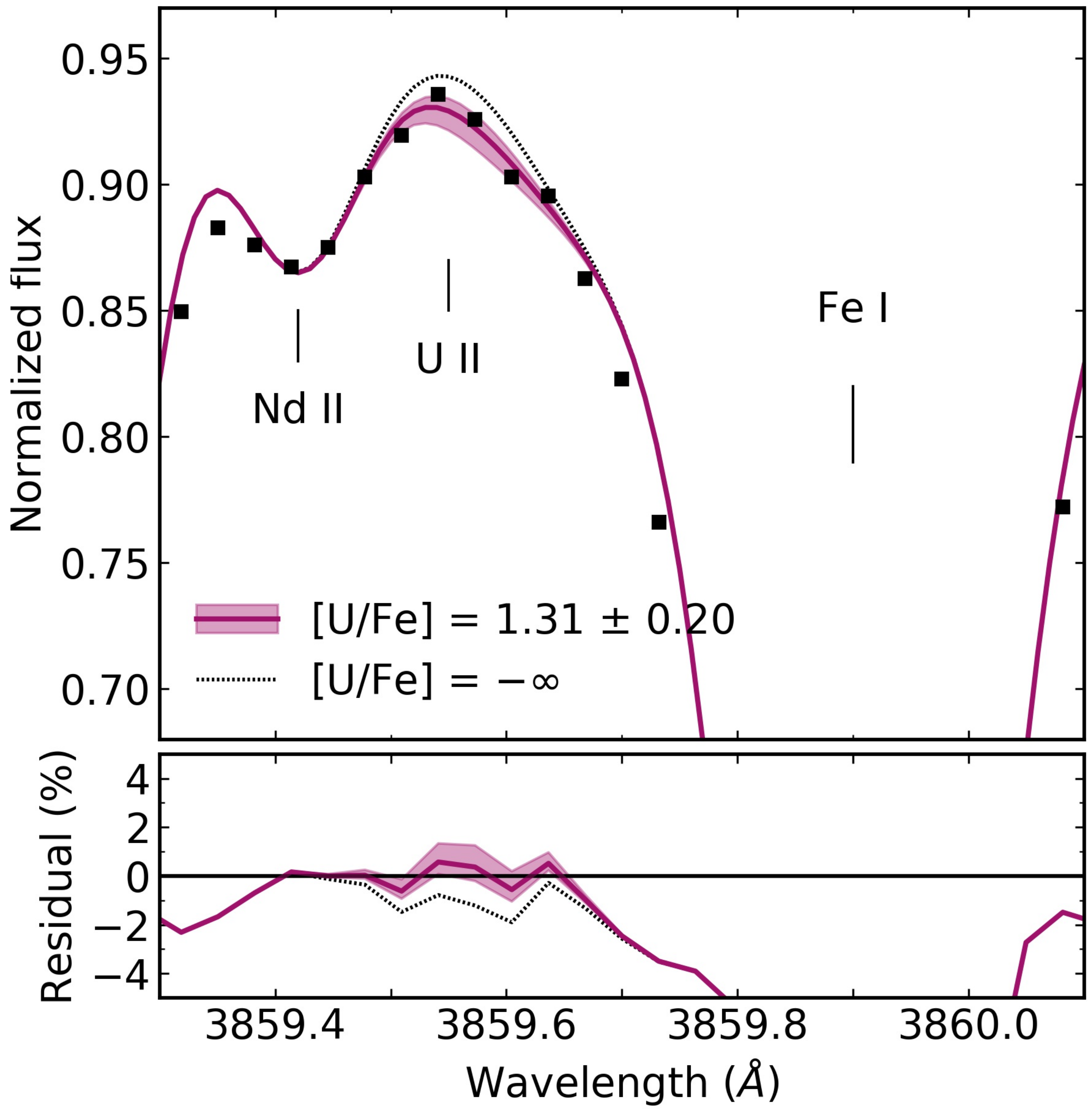


from data in McWilliam+ (1995), Sneden+ (2003)

RPA

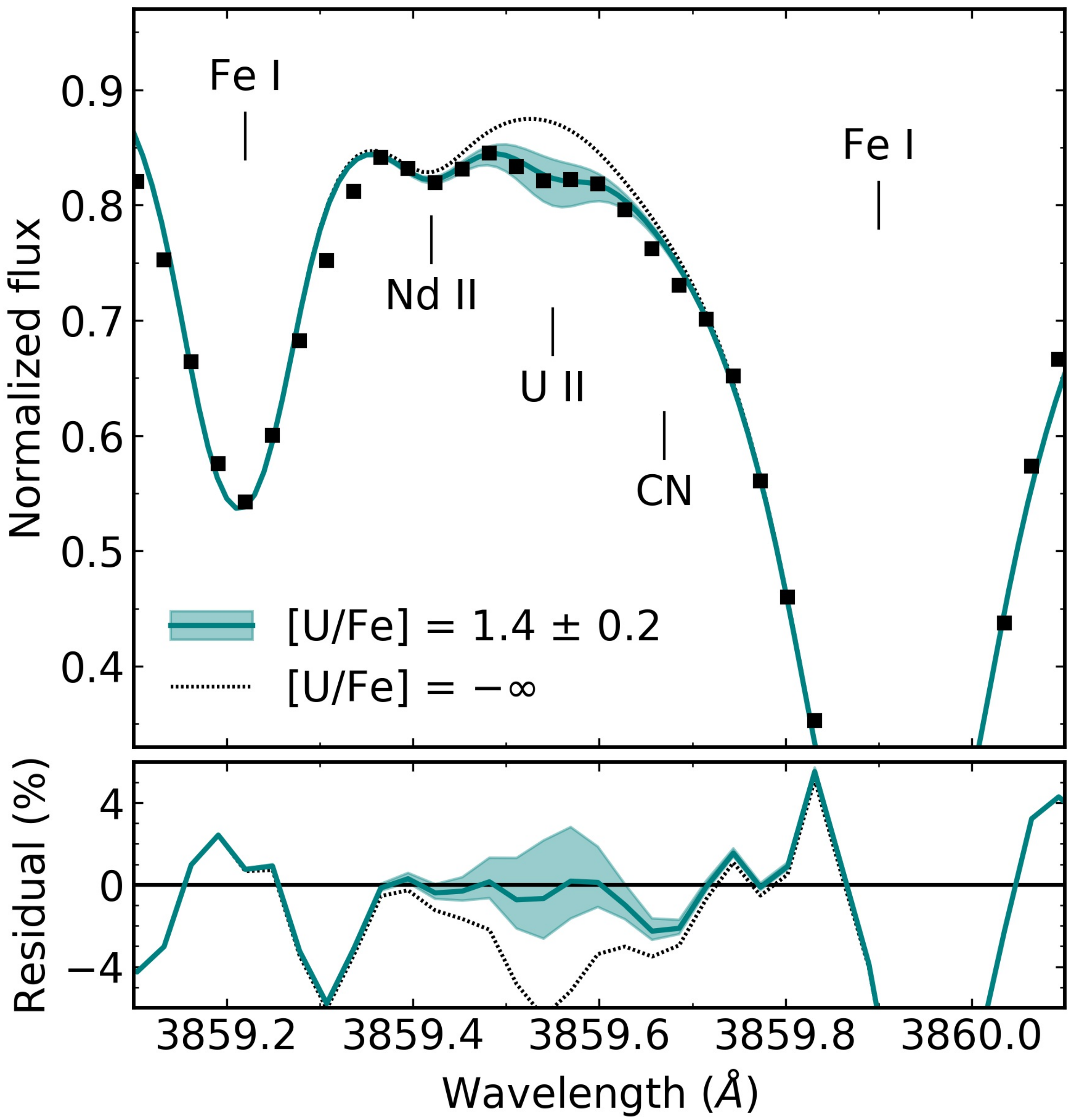
R-Process Alliance

Uranium in RAVE J203843.2-002333

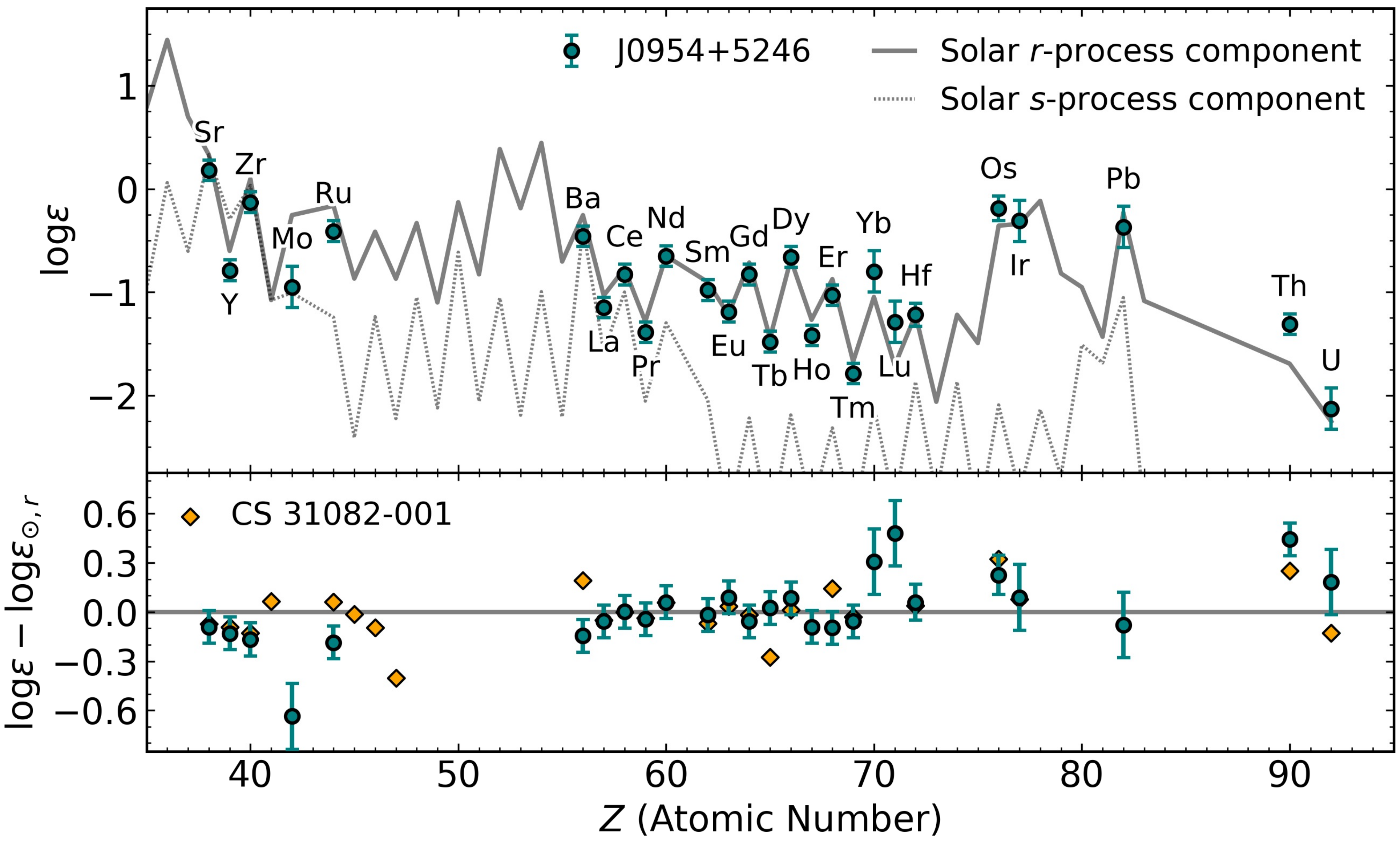


(2017)

Uranium in J0954+5246

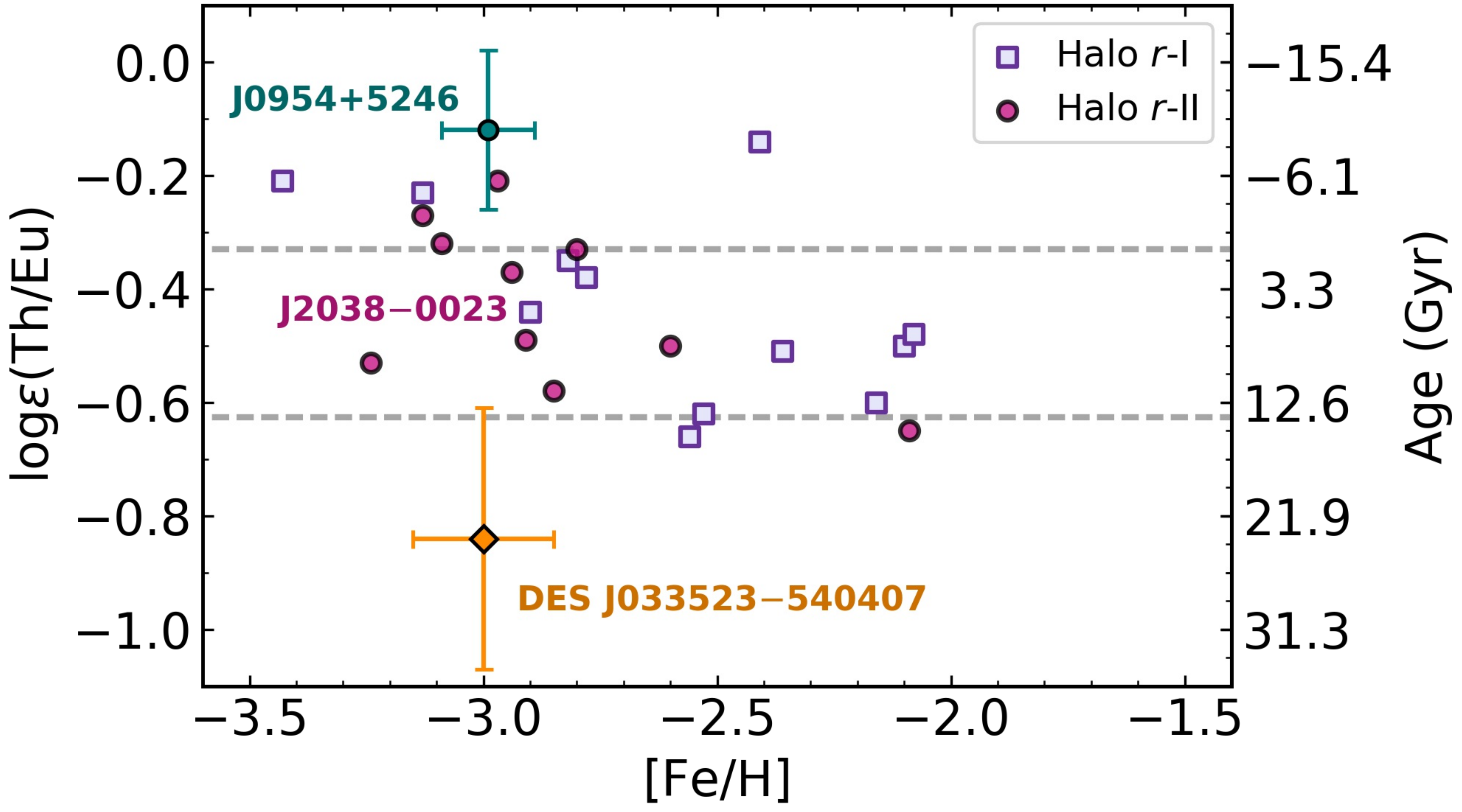


The actinide boost and J0954+5246



Holmbeck+ (2018)

Ages and cosmochronometry



Holmbeck+ (2018)

Ages and cosmochronometry

232-Th and 238-U are radioactive

Allows radioactive decay dating

$$t = 46.67\ \mathrm{Gyr}\left[\log\epsilon(\mathrm{Th/Eu})_0 - \log\epsilon(\mathrm{Th/Eu})_{\mathrm{obs}}\right]$$

$$t = 14.84\ \mathrm{Gyr}\left[\log\epsilon(\mathrm{U/Eu})_0 - \log\epsilon(\mathrm{U/Eu})_{\mathrm{obs}}\right]$$

$$t = 21.80\ \mathrm{Gyr}\left[\log\epsilon(\mathrm{U/Th})_0 - \log\epsilon(\mathrm{U/Th})_{\mathrm{obs}}\right]$$

Actinides and the r-process

Can varying levels of neutron richness
in a NSM account for the actinide boost?

PRISM

M. Mumpower and T. Sprouse

Low-entropy dynamical (tidal) ejecta of a NSM
(Korobkin+ 2012; Rosswog+ 2013)

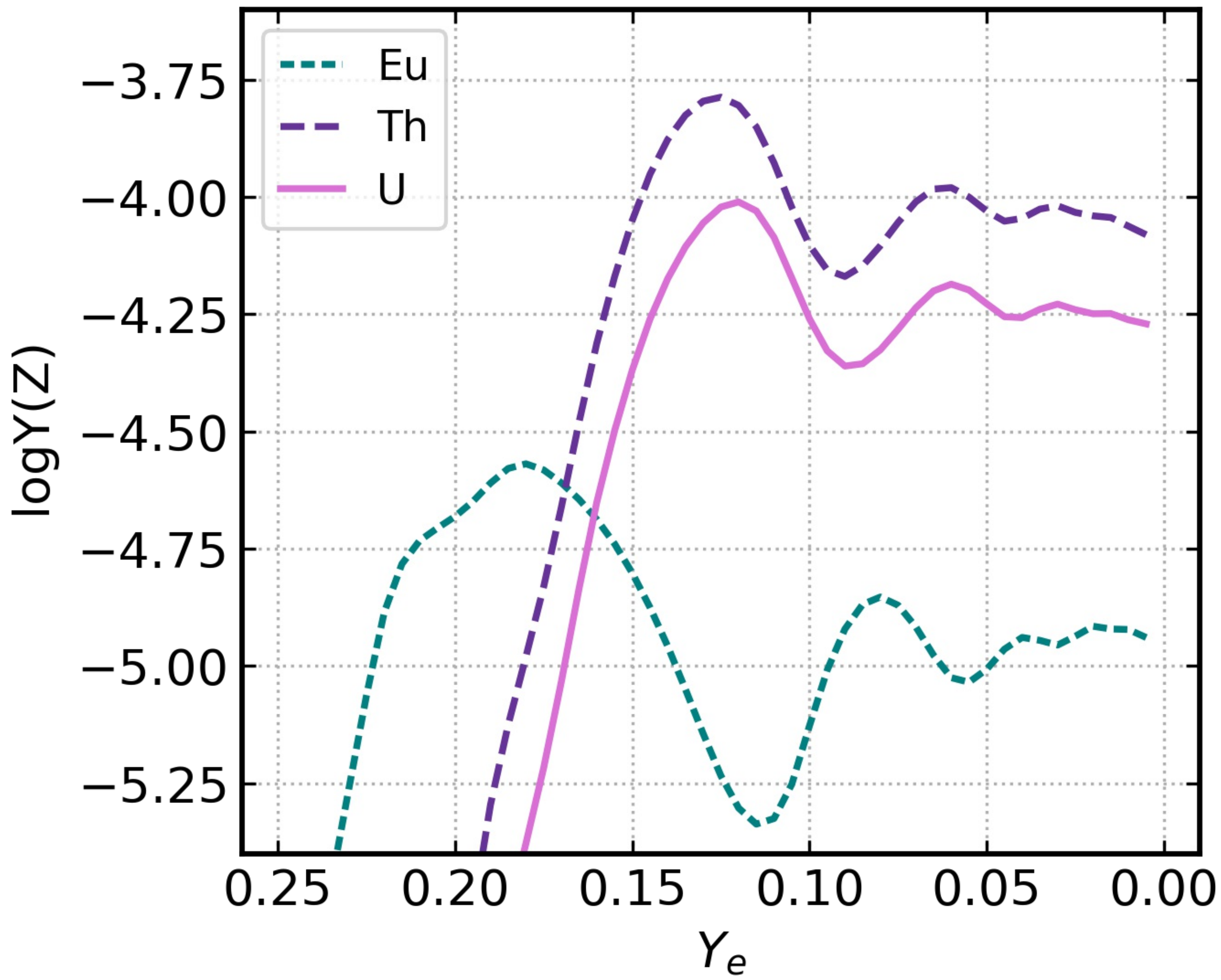
Vary the initial electron fraction: $Y_e = 0.005 - 0.250$

$$Y_e = [1 + (n/p)]^{-1}$$

Actinide and lanthanide production

Holmbeck with PRISM (T. Sprouse and M. Mumpower)

Actinide and lanthanide production



Ages and cosmochronometry

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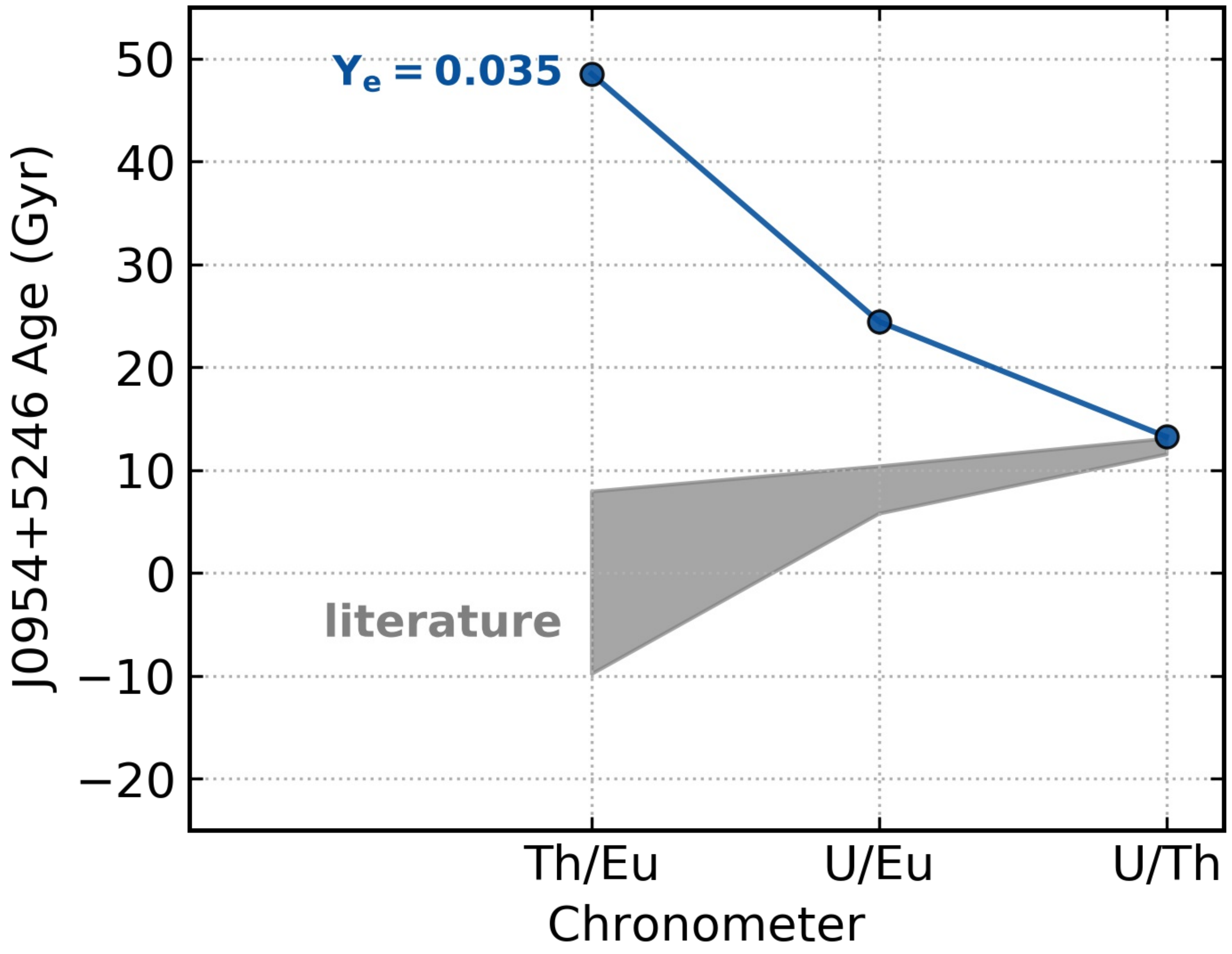
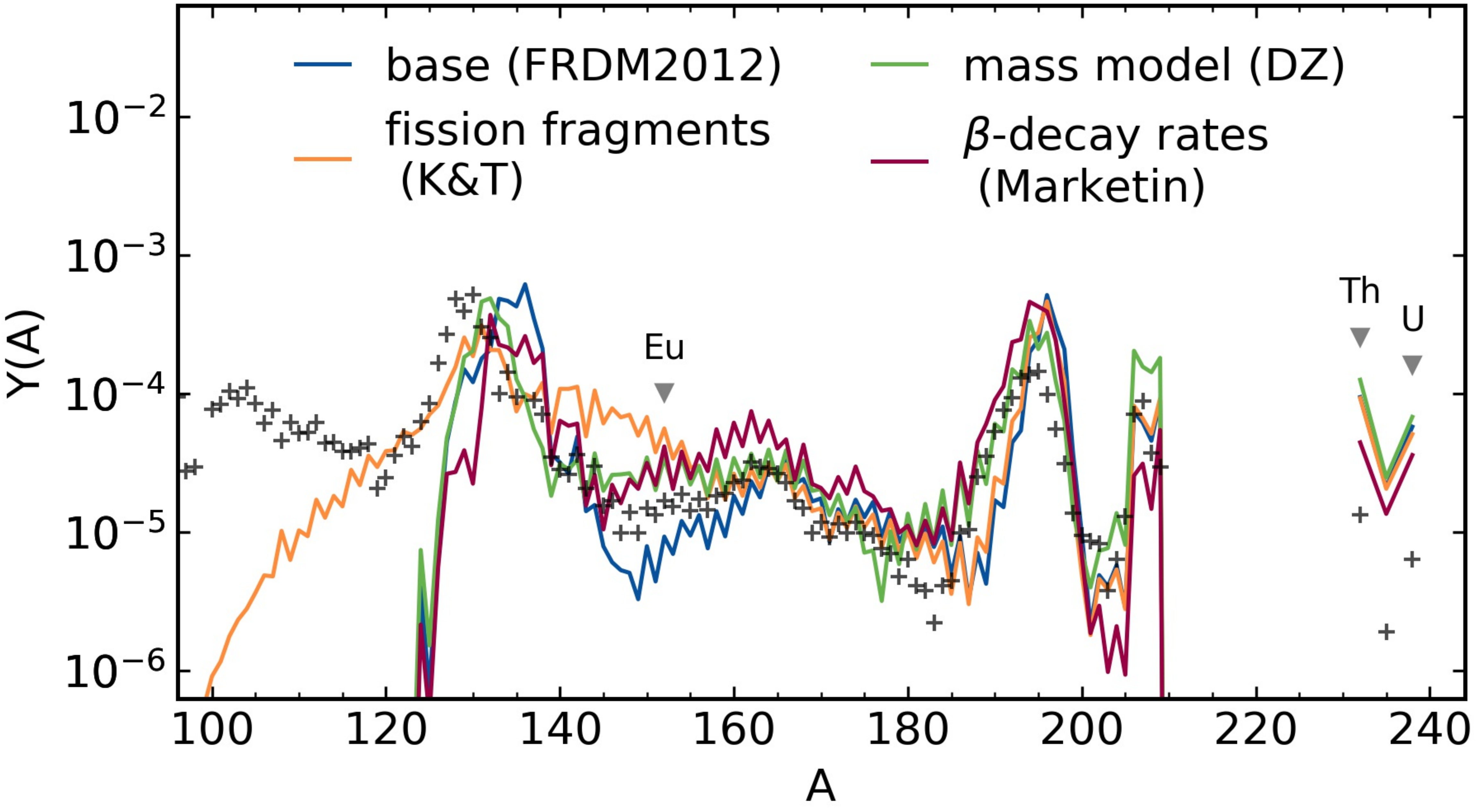
The age of J0954+5246

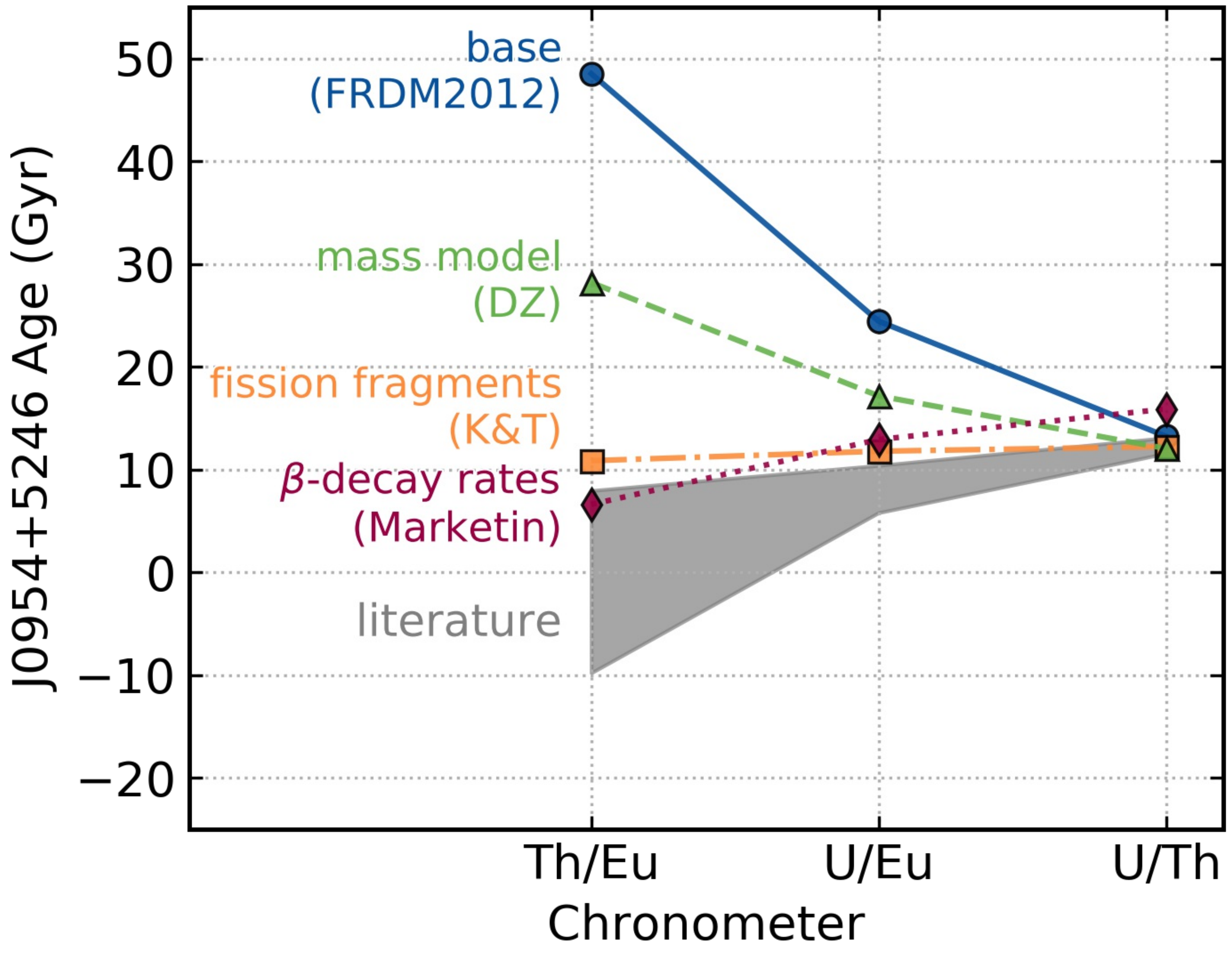


Holmbeck+ (2019)

Nuclear physics variations



The age of J0954+5246



Holmbeck+ (2019)

Actinides are currently not observed at such high levels

Need a method to dilute the actinides to reduce the Th/Eu production ratio

Actinide-Dilution model

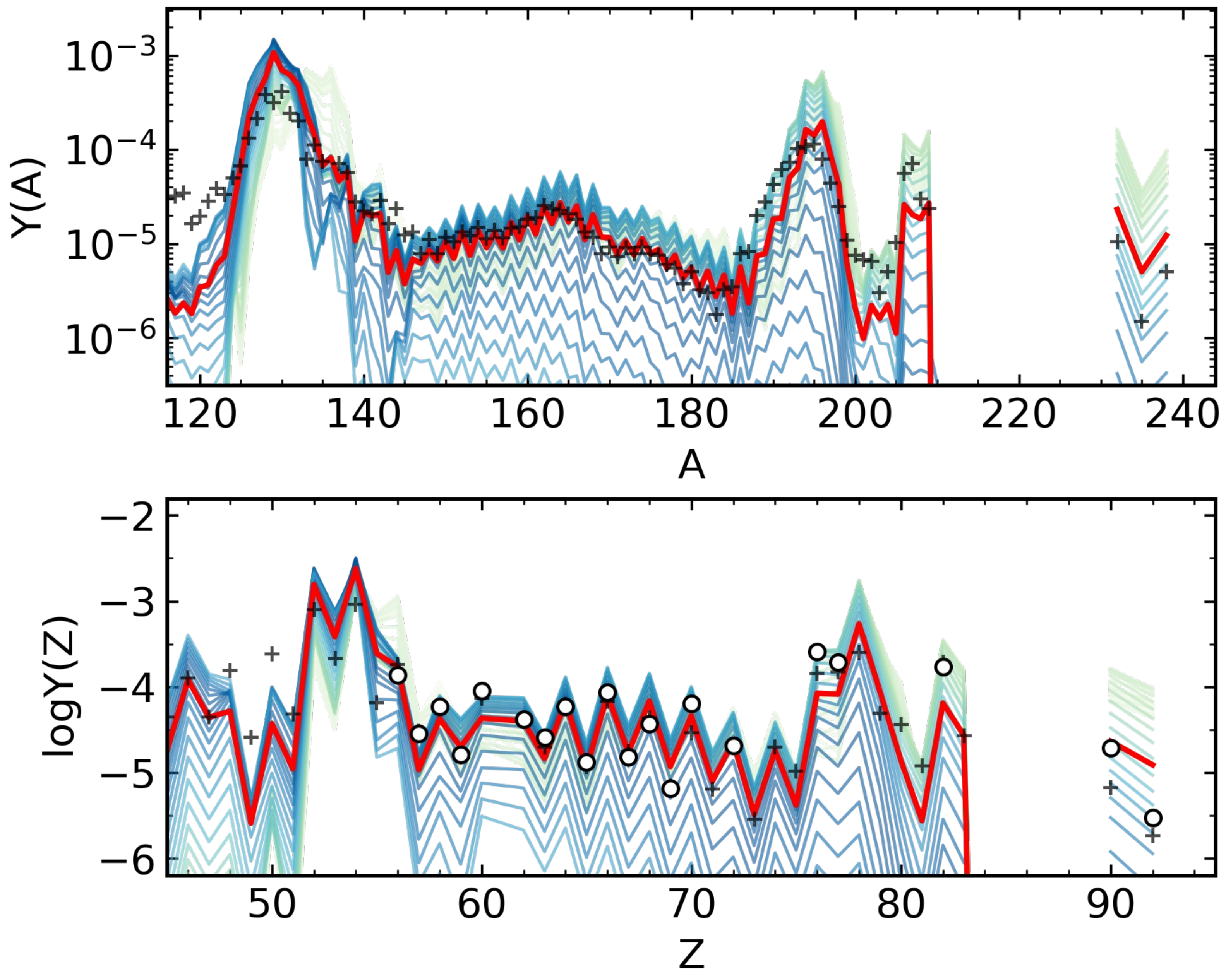
Distribution of Y_e

Tidal ejecta
($Y_e \approx 0.16$, Bovard+ 2017)

Disk wind
($Y_e \approx 0.22$; Lippuner+ 2017)

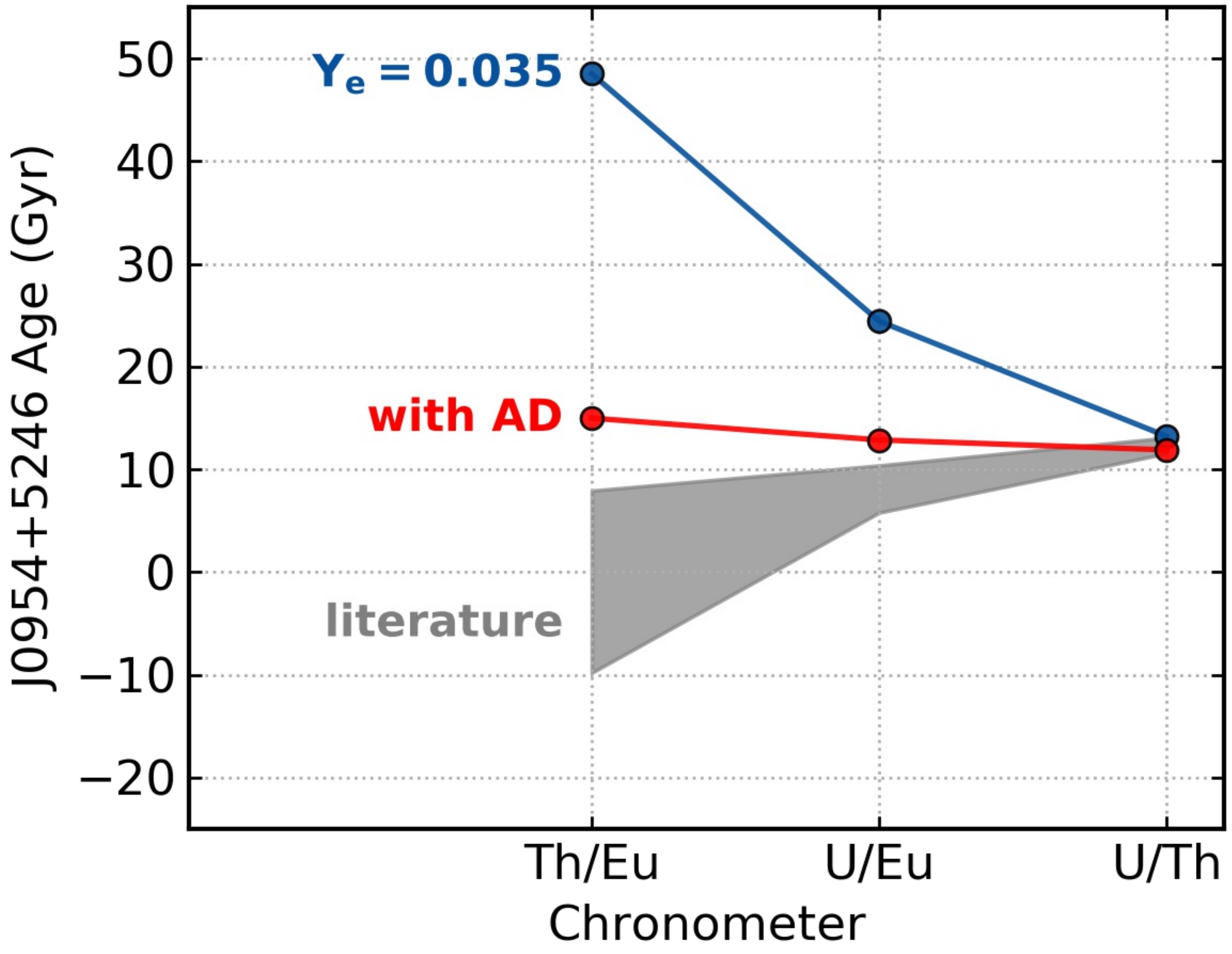
$m_{\mathrm{wind}} / m_{\mathrm{dyn}} = 3$
from estimates of **GW170817**
(Rosswog+ 2017; Tanaka+ 2017)

Actinide-Dilution model



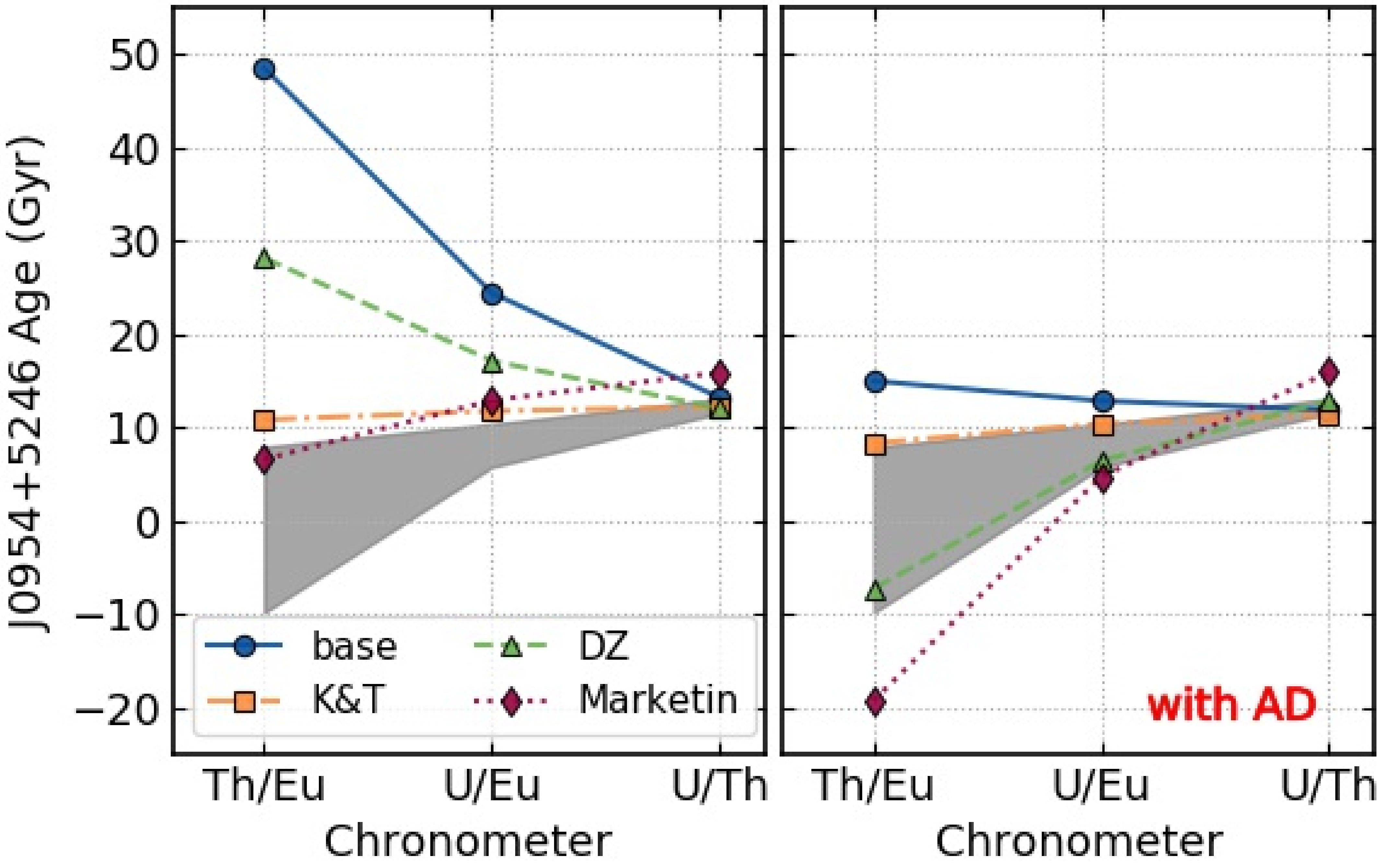
Holmbeck+ (2019)

Ages



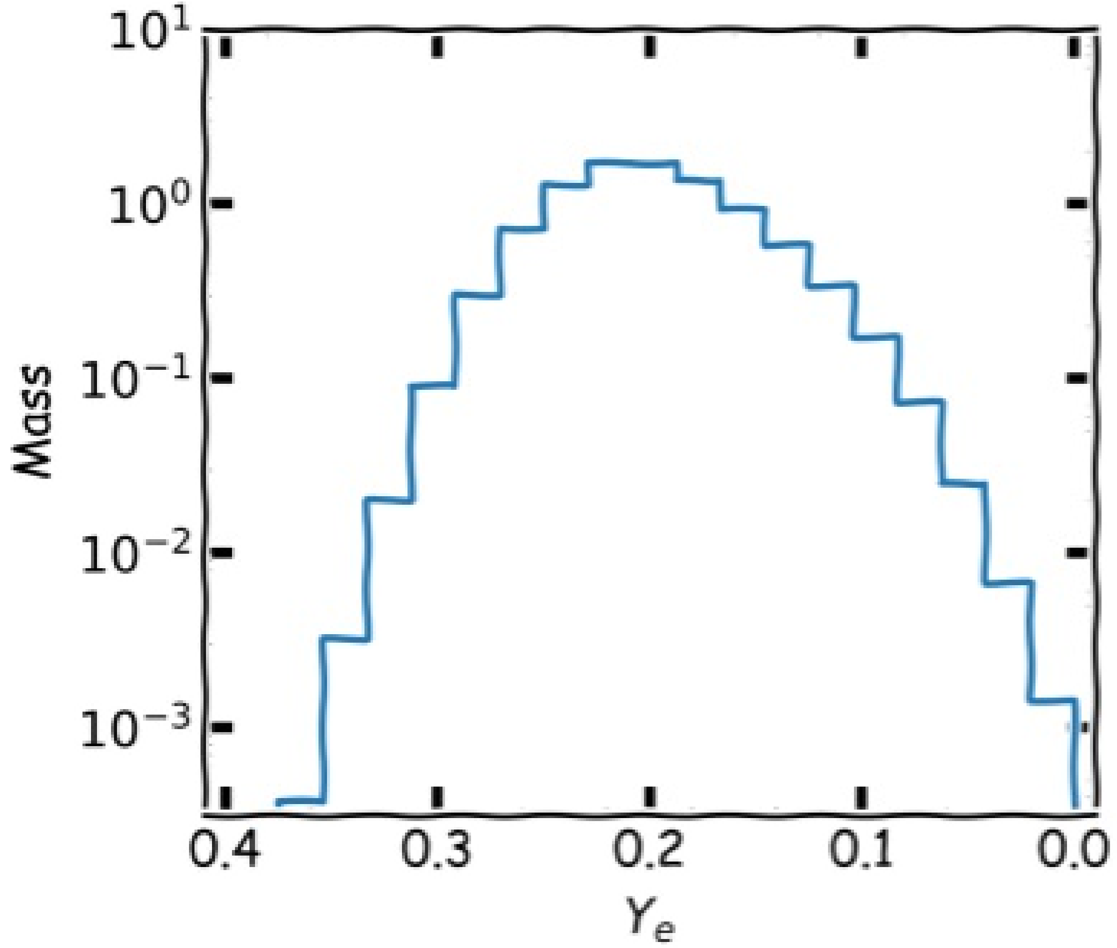
Holmbeck+ (2019)

Ages

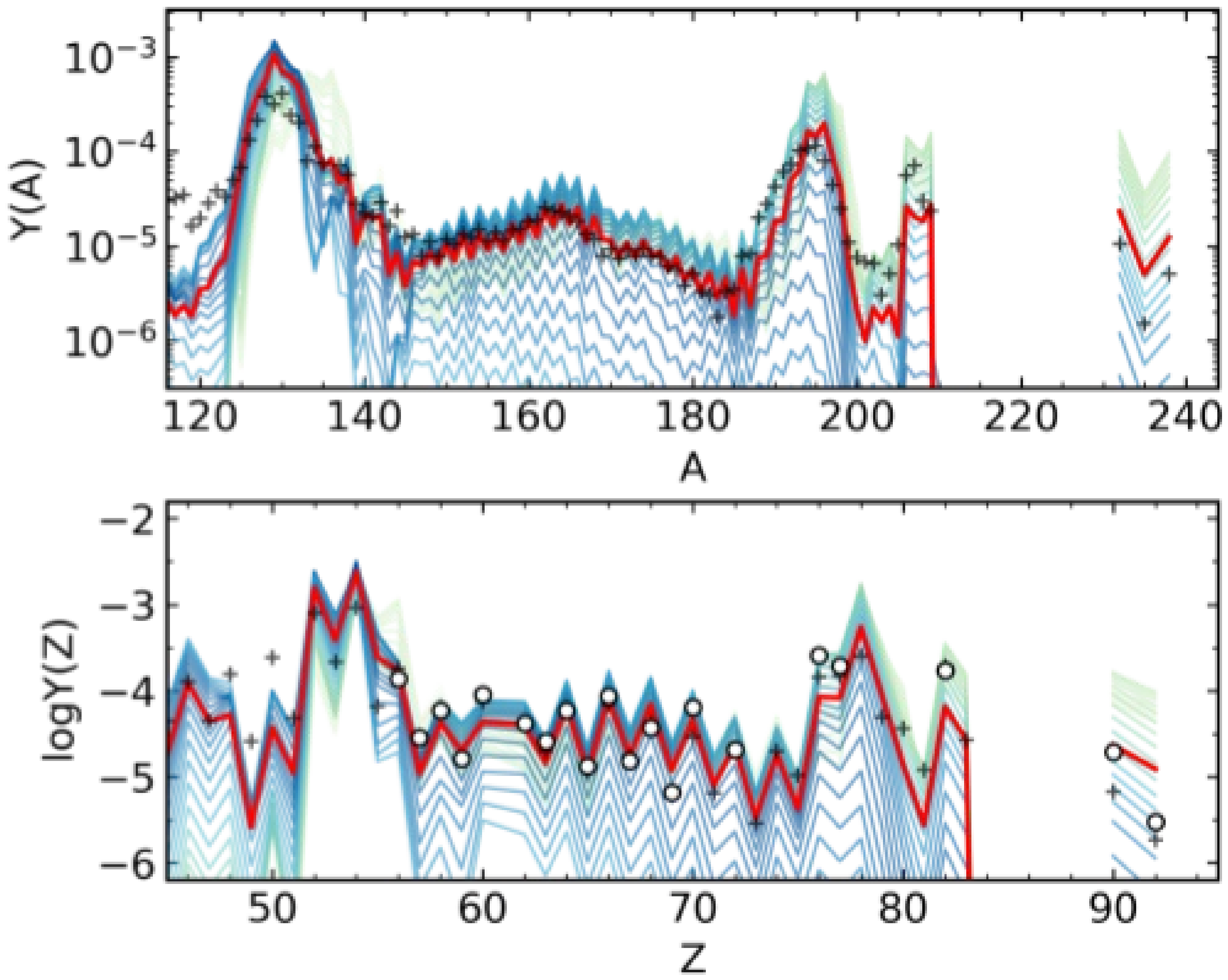


J0954+5246 Age (Gyr)
50
40
30
20
10
0
−10
−20
base
K&T
DZ
Marketin
Th/Eu
U/Eu
U/Th
Chronometer
with AD

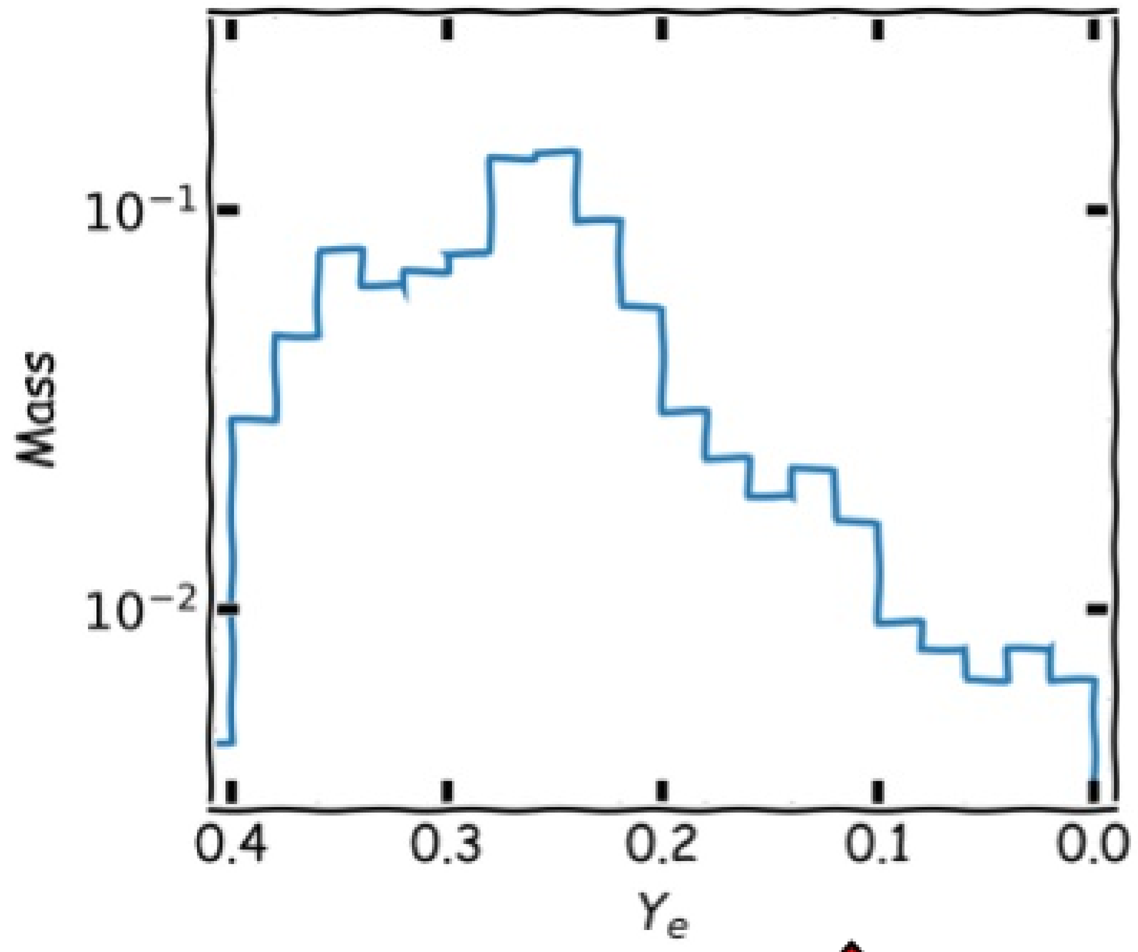
AD Model

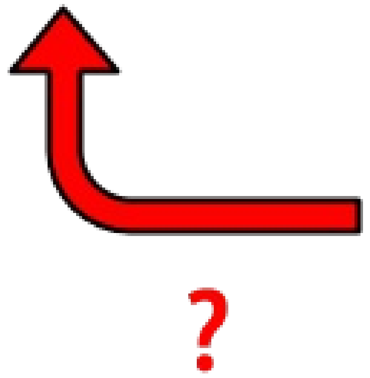


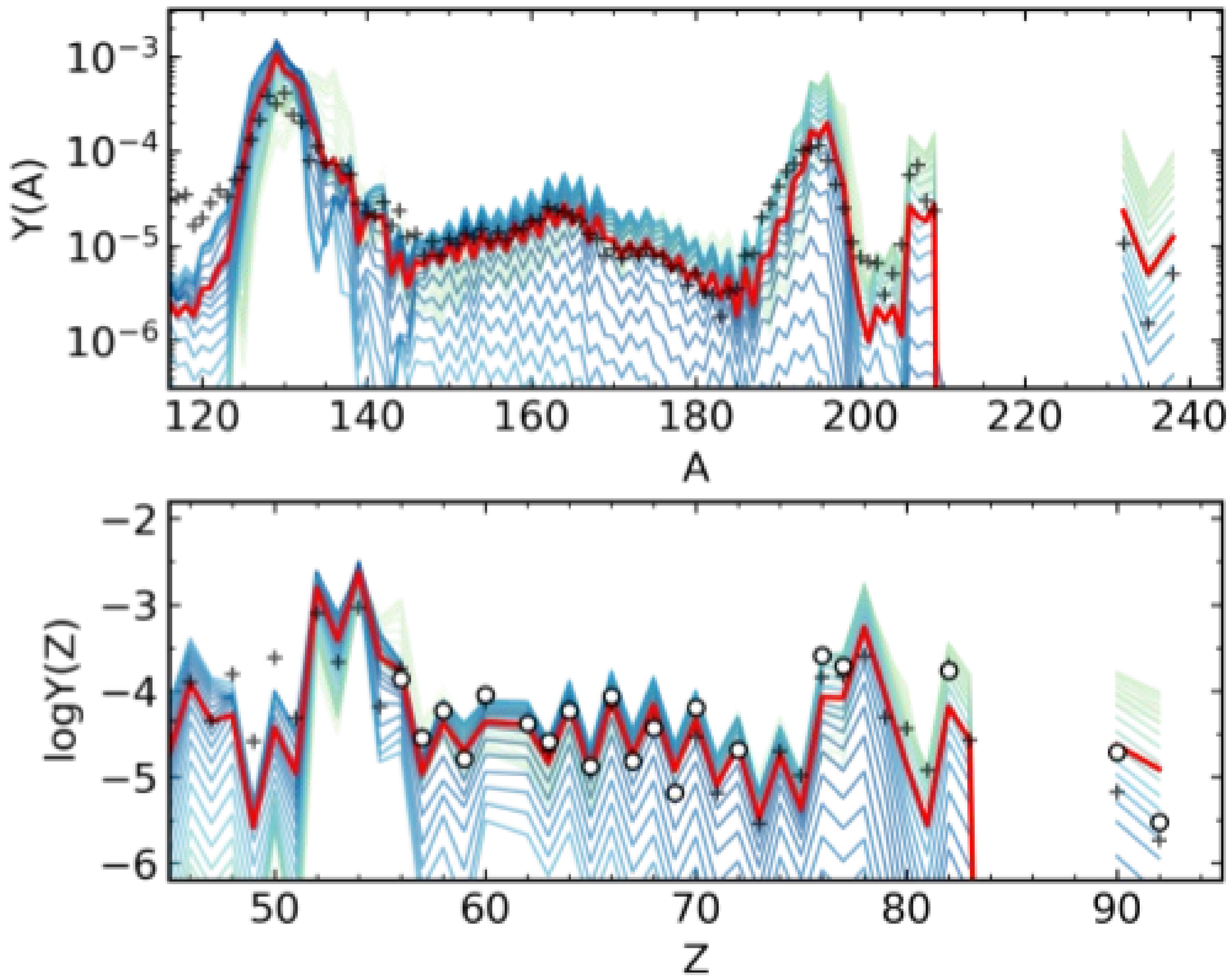
AD



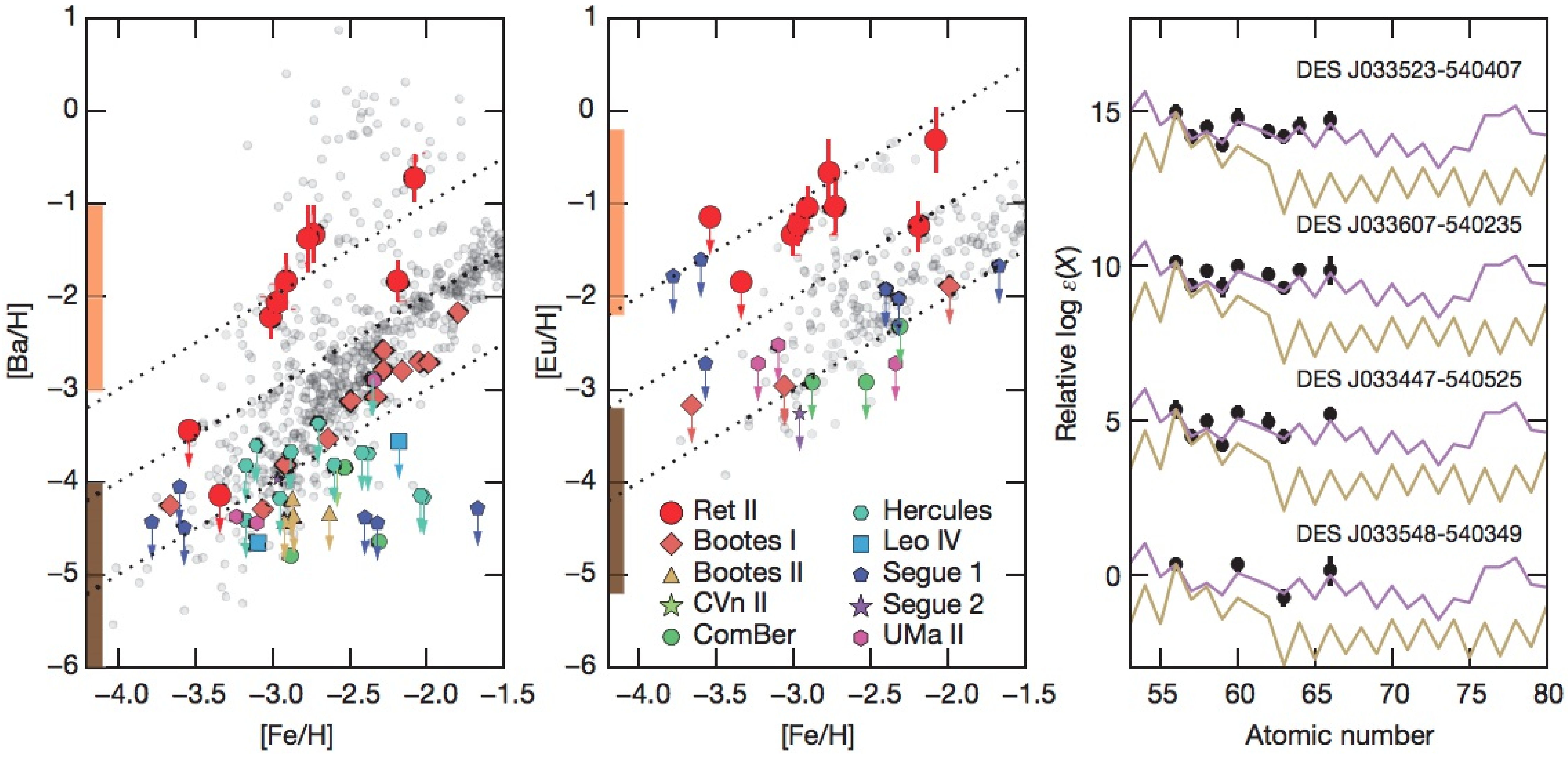
Can we go backwards?





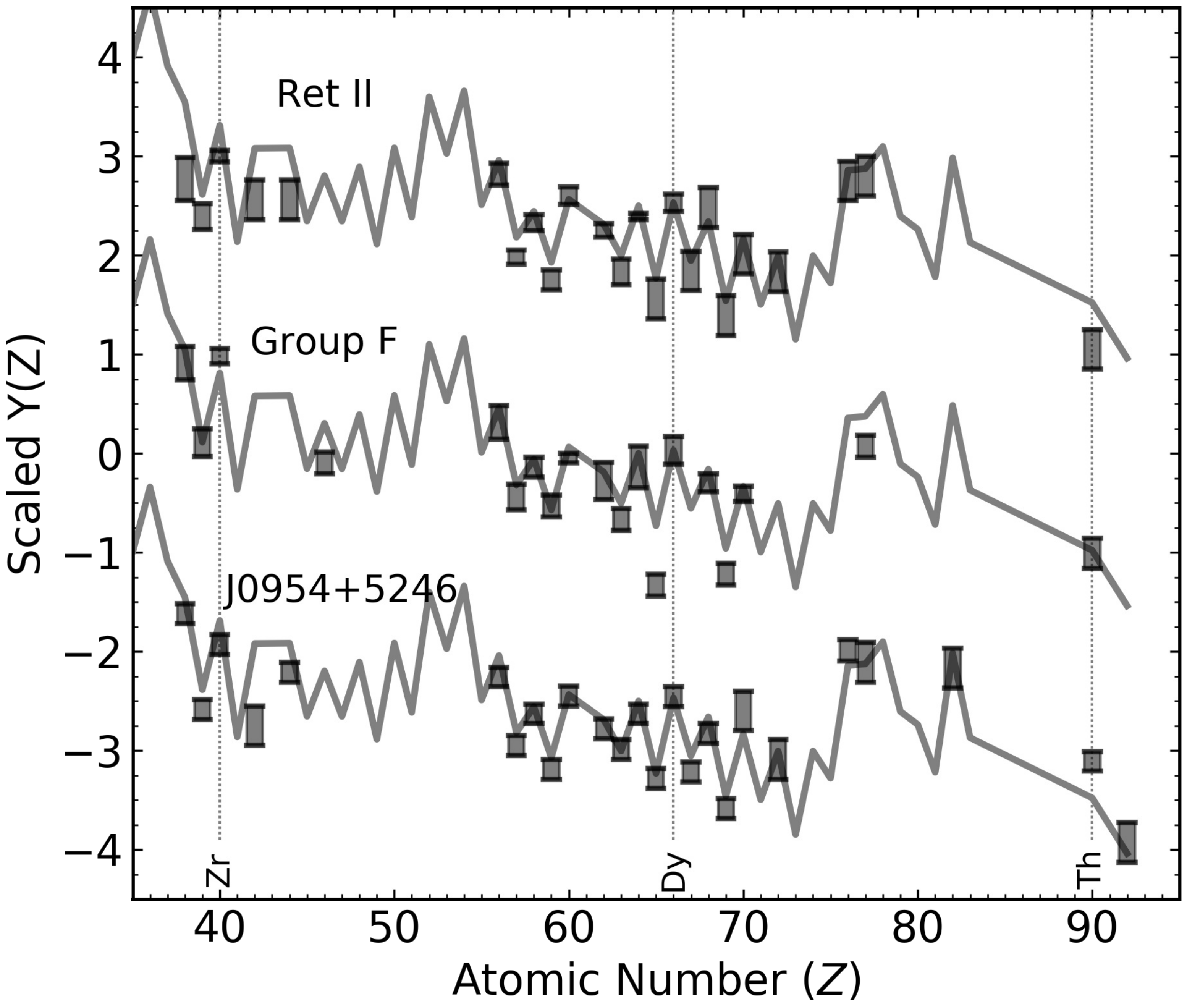


Reticulum II



Ji+ (2016)

Groups of r-process enhanced stars



Assume one event

that produces the entire r-process pattern

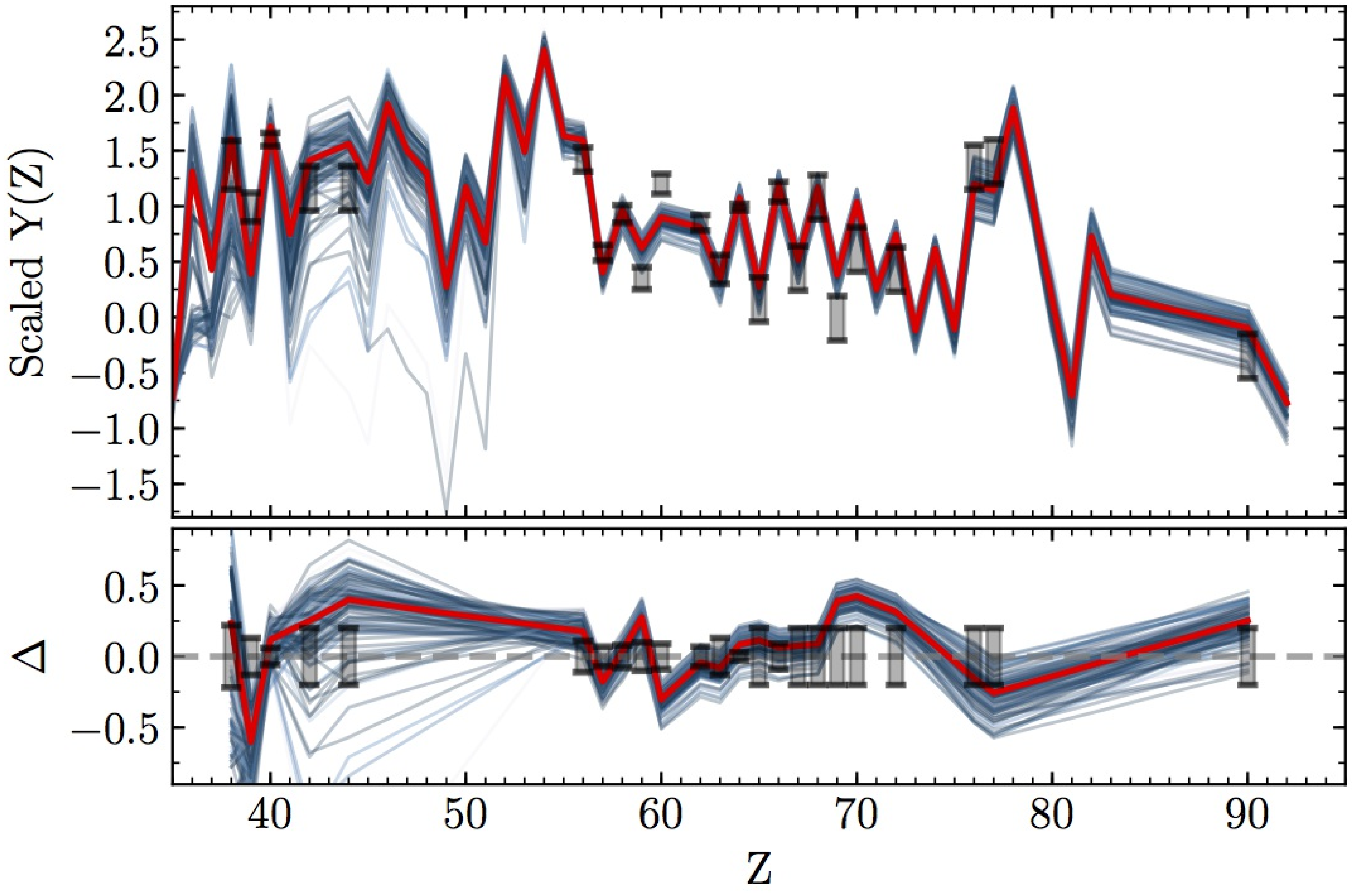
Not necessarily an NSM

Actinide-Dilution with Matching model

Builds empircal mass ejecta distributions as a function of Y_e (0.005-0.450)

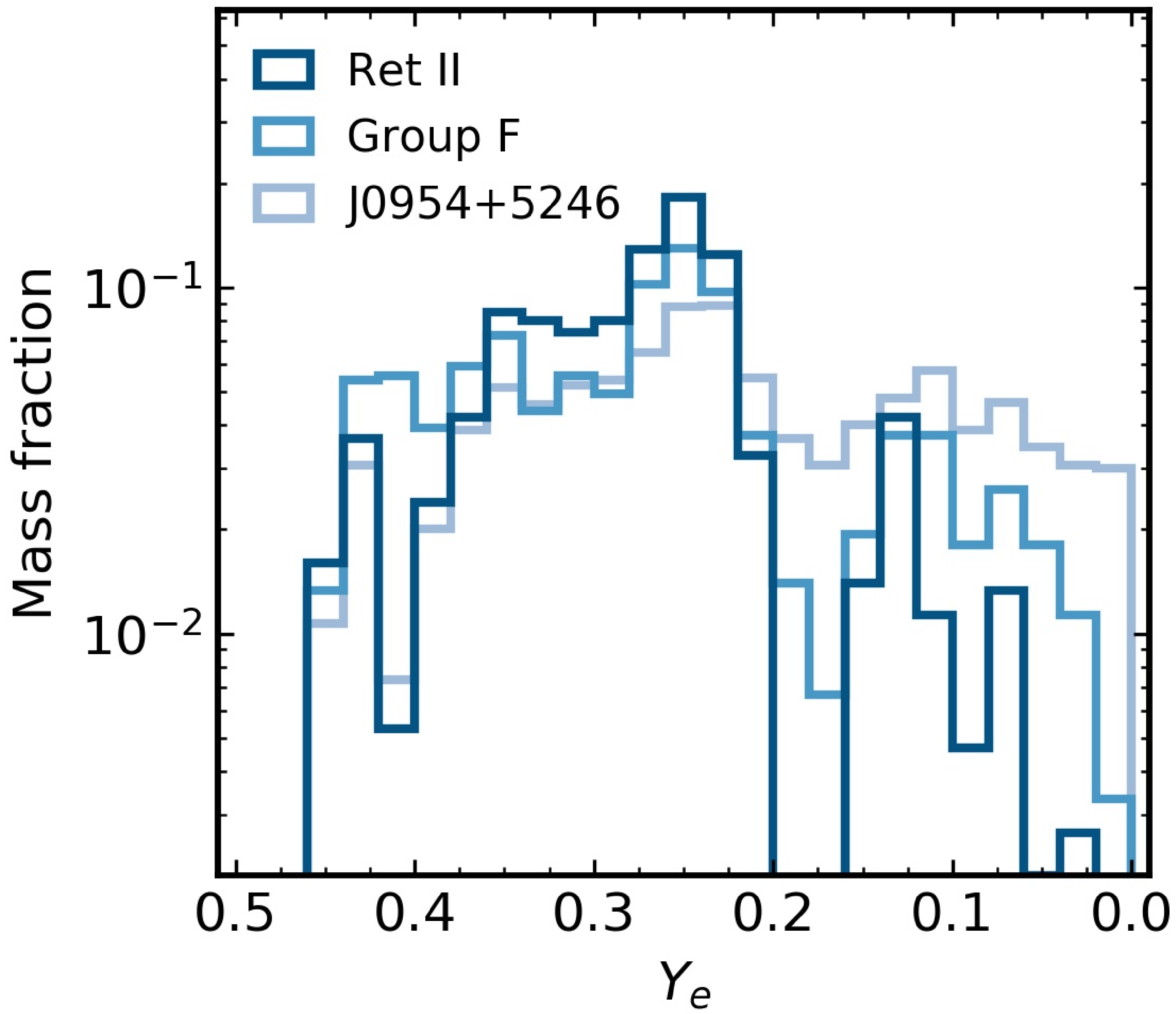
To explain entire pattern from Zr to U

ADM abundance pattern for Ret II

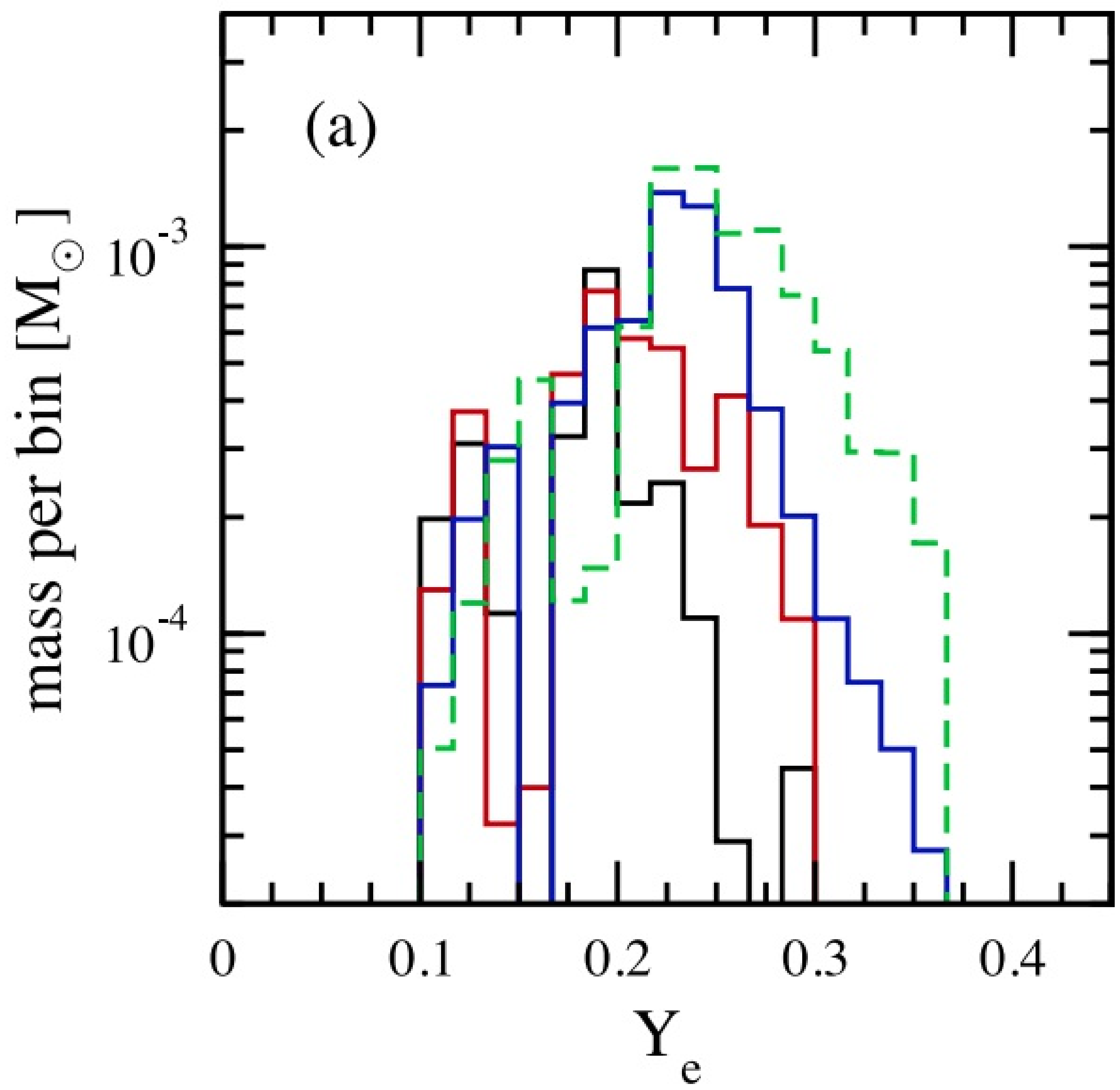


Holmbeck+ (in prep. 2019)

Empirically built ejecta mass distributions

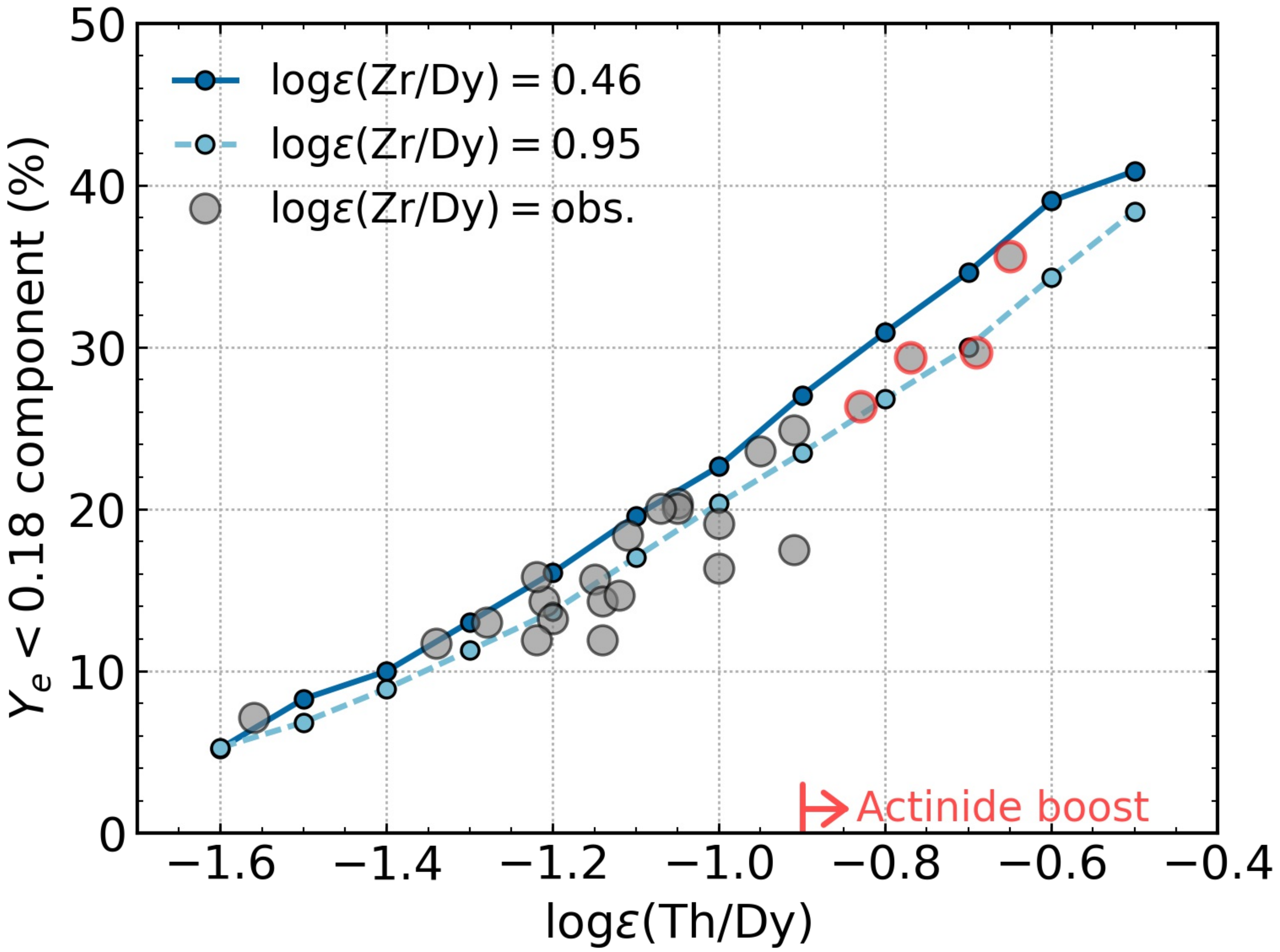


NSM ejecta (literature)



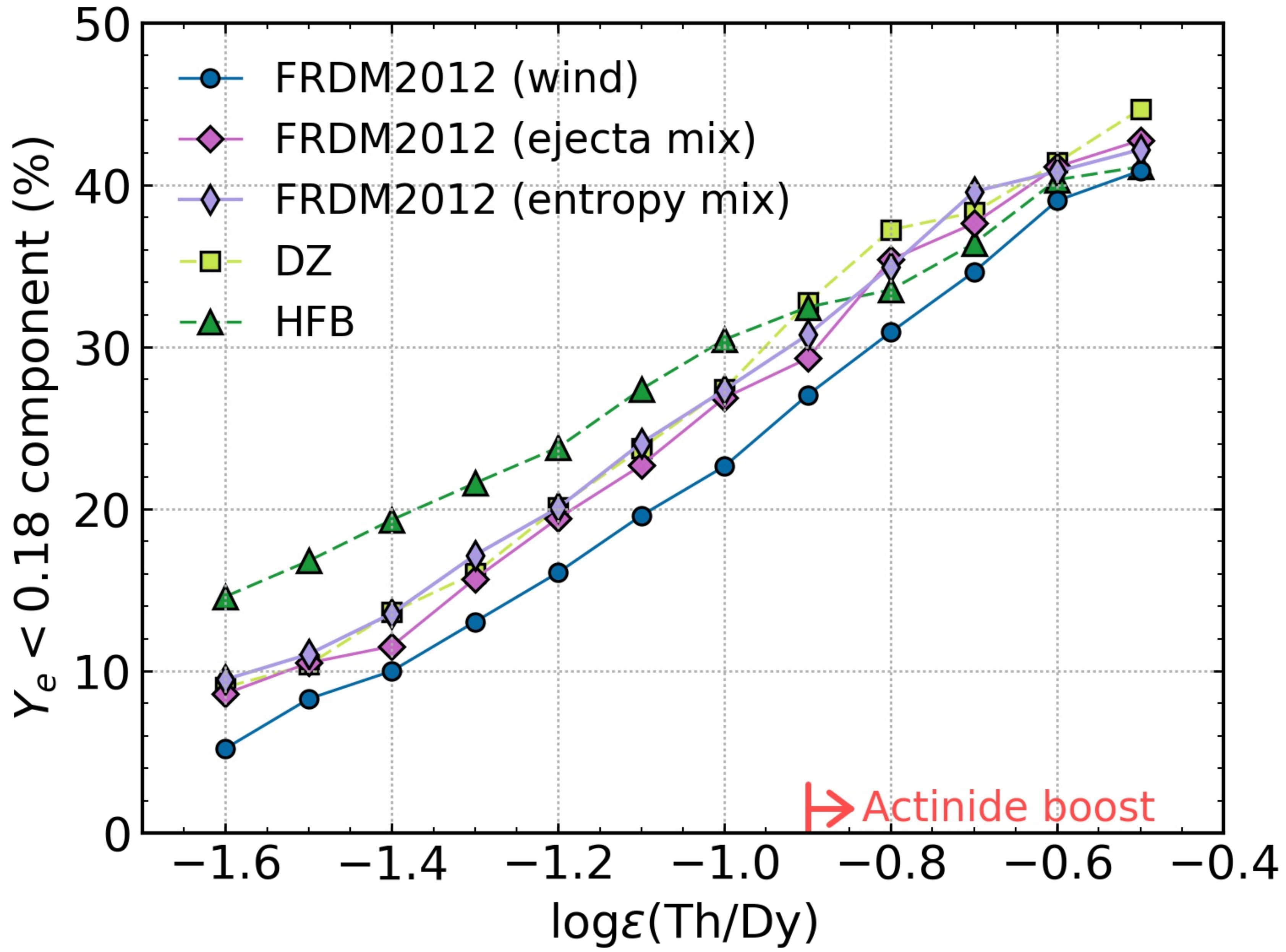
Fernandez+ (2015)

The low-Ye component



Holmbeck+ (in prep. 2019)

Low-Ye component under variations



Holmbeck+ (in prep. 2019)

Actinide-boost stars do not call for a separate r-process progenitor

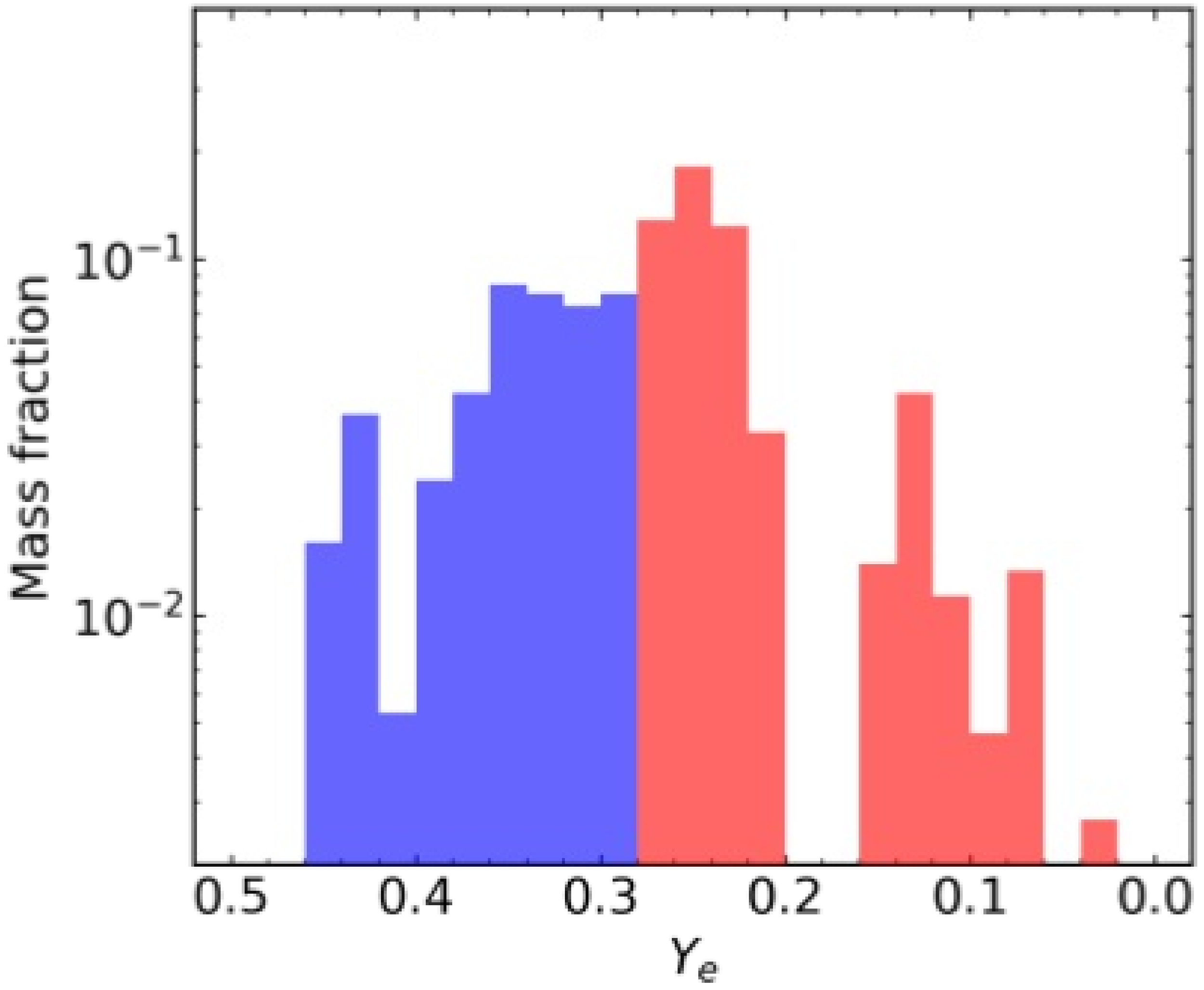
Is this source an NSM?

Ret II

$X_{lan} = 10^{-3.8}$

$X_{lan} = 10^{-0.8}$

$m_{\mathrm{red}}/m_{\mathrm{bue}} = 1.6$

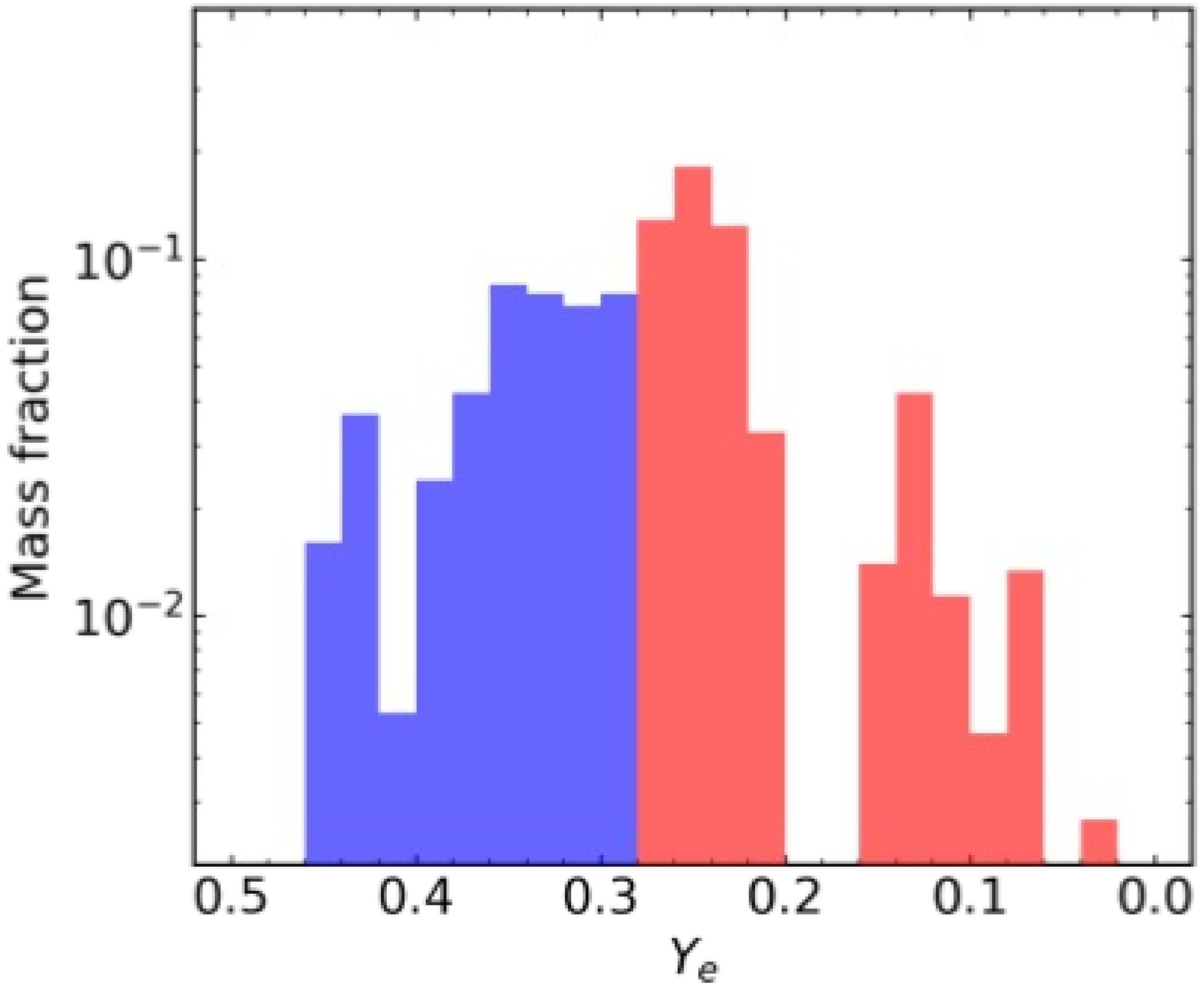


Ret II

$X_{lan} = 10^{-3.8}$

$X_{lan} = 10^{-0.8}$

$m_{red}/m_{bue} = 1.6$



GW170817

$X_{lan} = 10^{-4}$

$X_{lan} = 10^{-1.5}$

$m_{red}/m_{bue} = 1.7$

(Kasen+ 2017)

Results derived from r-II stars agree* with NSM observation

Summary and Outlook

The actinides are *over*-produced in very cold, neutron-rich (tidal) ejecta

NSMs could still be an actinide-boost source if most of the ejecta mass does not contribute actinides

The same *r*-process source can in principle account for observed actinide variations

How do the empirically built ejecta distributions compare to NSM simulations?

Entropy, dynamical timescale, nuclear physics variations...

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