

SNAQs January 2022

# Actinide-Dating Stars: Nuclear Uncertainty in Cosmic Age

Kelsey Lund

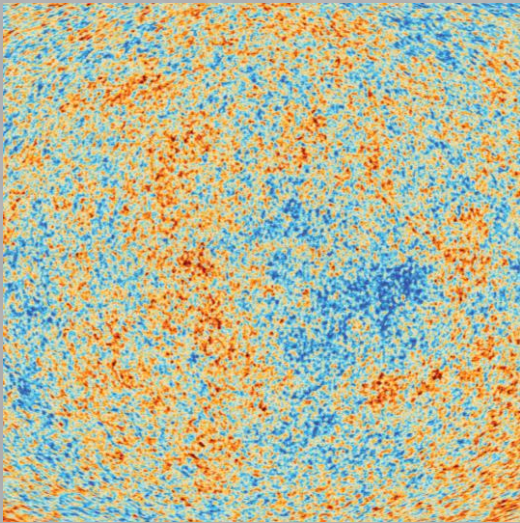
12 January 2022

NC STATE  
UNIVERSITY



How old is the universe?

# How old is the universe?



Cosmological models,  
cosmic expansion



Very old stars



# How old is the universe?

Old stars provide a lower limit for the age of the universe (it is *at least* as old as the things in it)

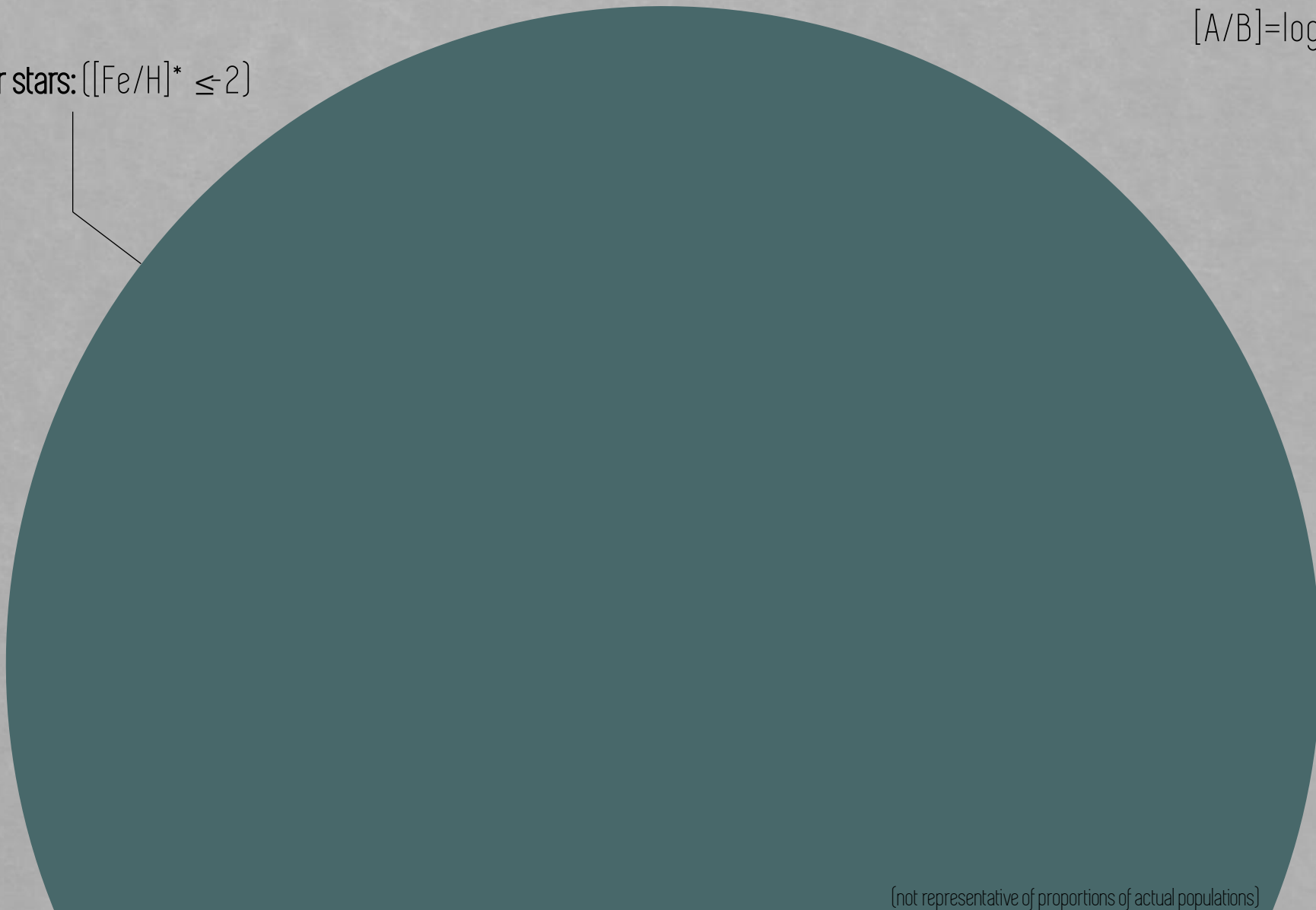


Very old stars

Metal-poor stars:  $([Fe/H]^* \leq -2)$

$$[A/B] = \log(N_A/N_B)_{\text{obs}} - \log(N_A/N_B)_{\text{Sun}}$$

$$\log_{\epsilon}(A) = \log_{10}(N_A/N_H) + 12$$



(not representative of proportions of actual populations)

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r-ii stars:  $[[\text{Eu}/\text{Fe}] > +1]$

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r-II stars:  $[[\text{Eu}/\text{Fe}] > +1]$

Actinide “boost”:  $\log_{\epsilon}(\text{Th}/\text{Dy}) > -0.9$

Actinide “normal”:  $-1.20 \leq \log_{\epsilon}(\text{Th}/\text{Dy}) \leq -0.9$

Actinide “deficient”:  $\log_{\epsilon}(\text{Th}/\text{Dy}) < -1.20$

(not representative of proportions of actual populations)

**Basic Initial Assumption:** Metallicity is a good approximation for age

- Estimated age of Milky Way r-ii stars is ~11-12 Gyr (Snedden+2008, Roederer+ 2014)



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$$t = 14.84 \text{ Gyr} \left[ -\log_{\epsilon} \left( \frac{\text{U}}{\text{Eu}} \right)_{\text{obs}} + \log_{\epsilon} \left( \frac{\text{U}}{\text{Eu}} \right)_0 \right]$$

$$t = 21.80 \text{ Gyr} \left[ -\log_{\epsilon} \left( \frac{\text{U}}{\text{Th}} \right)_{\text{obs}} + \log_{\epsilon} \left( \frac{\text{U}}{\text{Th}} \right)_0 \right]$$

-  $^{232}\text{Th}$  &  $^{238}\text{U}$ : produced exclusively via r-process ( $t_{1/2} = 14 \text{ Gyr}, 4.486 \text{ Gyr}$  respectively)

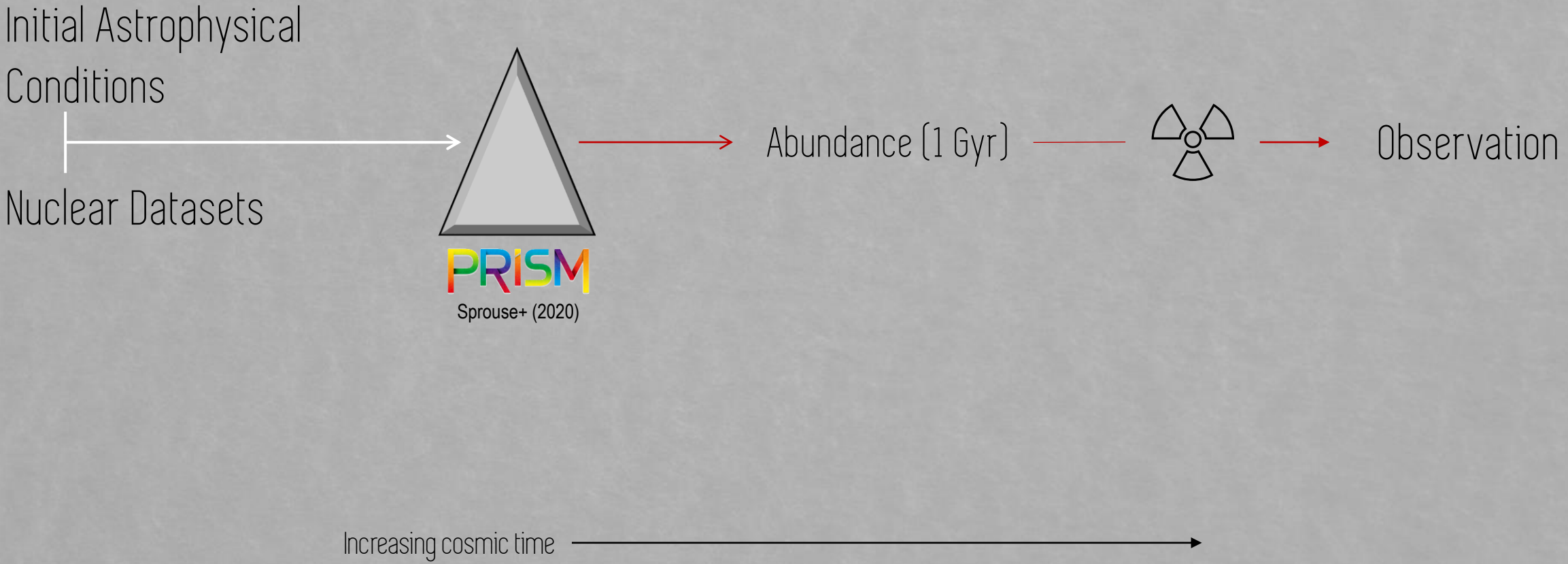
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 \end{array}$$

Final abundance of NSM simulation  
 =  
 “Initial” abundance of star

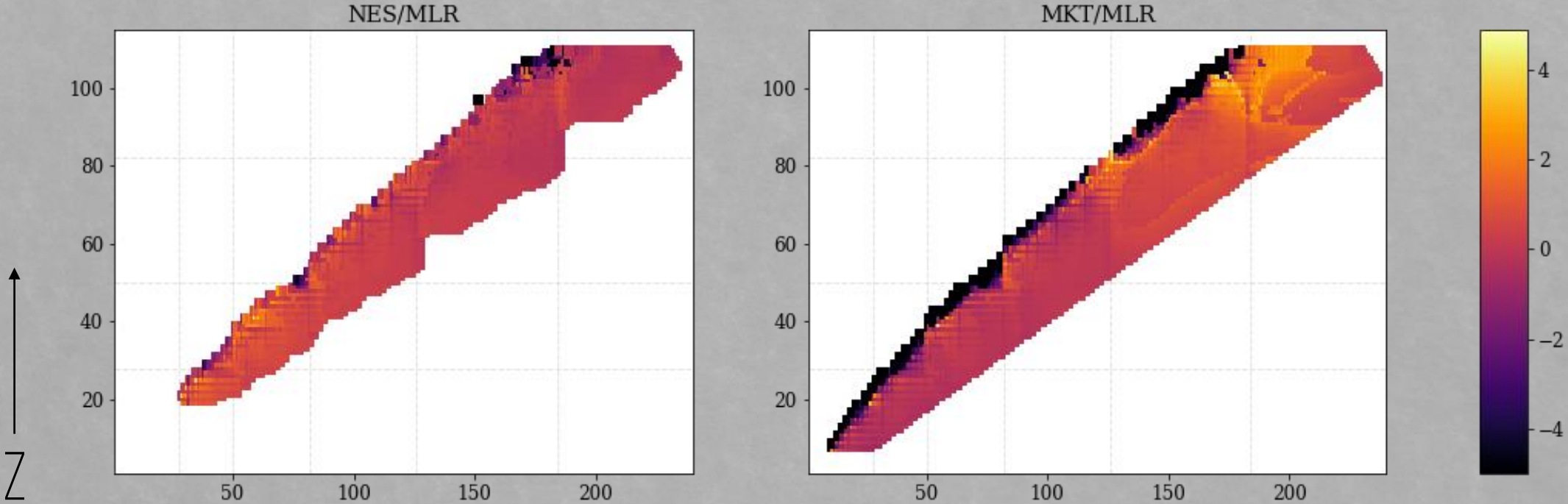
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Star Name	$\log_{\epsilon}(\text{Eu})$	$\log_{\epsilon}(\text{Th})$	$\log_{\epsilon}(\text{U})$	Reference
CS22892-052	-0.95	-1.57 (D)	-2.3	Snedden+2003
CS29497-004	-0.66	-1.16 (N)	-2.20	Hill+2017
CS31082-001	-0.72	-0.98 (N)	-1.92	Siquiera Mello+2013 Hill+2002
HE1523-0901	-0.62	-1.2 (D)	-2.06	Frebel+2007
J0954+5246	-1.19	-1.31 (B)	-2.13	Holmbeck+2018
J2038-0023	-0.75	-1.24 (N)	-2.14	Placco+2017

\*B, N, and D indicate whether a star is classified as actinide boost, normal, or deficient





(a) Log of rate ratios: Ney (2020) to Möller (2019)  
(b) Log of rate ratios: Marketin (2016) to Möller (2019)

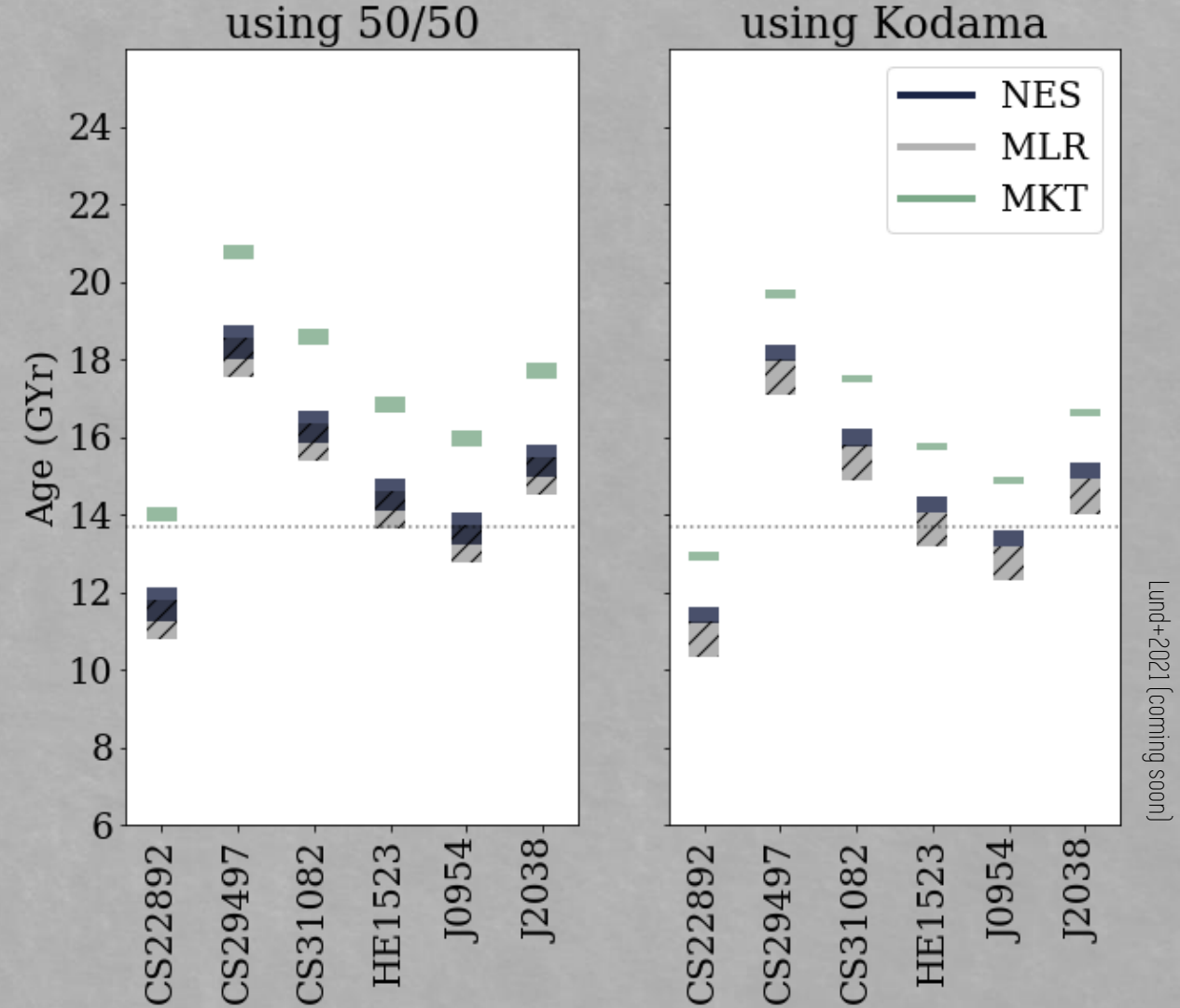
Marketin (MKT)

Möller (MLR)

Ney (NES)

~Longer half-life\* →

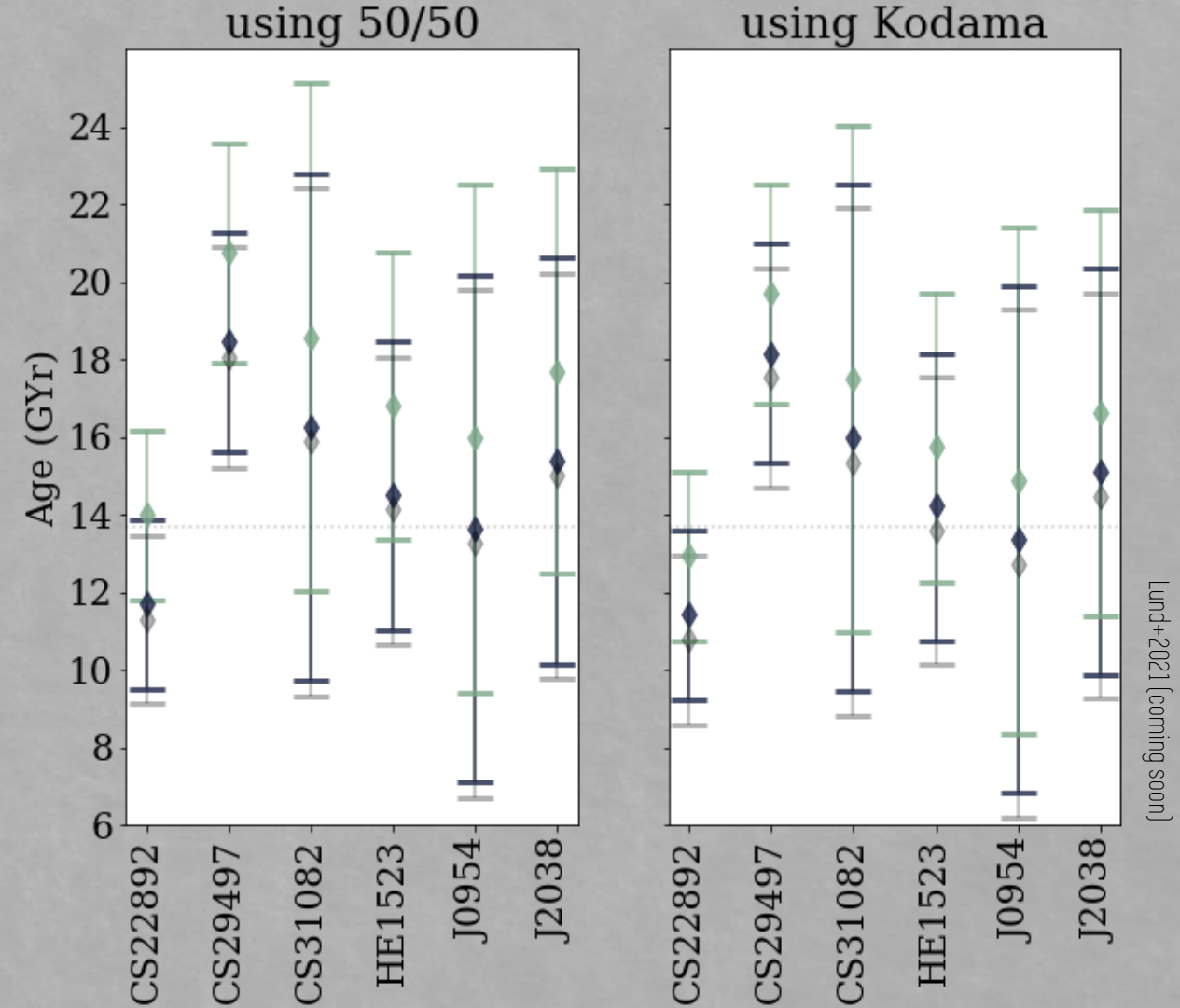
Range of age estimates based on theoretical U/Th ratios for all multiple-component trajectories



$$t = 21.80 \text{ Gyr} \left[ -\log_{\epsilon} \left( \frac{U}{Th} \right)_{\text{obs}} + \log_{\epsilon} \left( \frac{U}{Th} \right)_0 \right]$$

Range of age estimates taking central theory value (previous slide) and adding observational error bars

Still only using actinide abundance ratios!



Lund+2021 (coming soon)

We have more information available!

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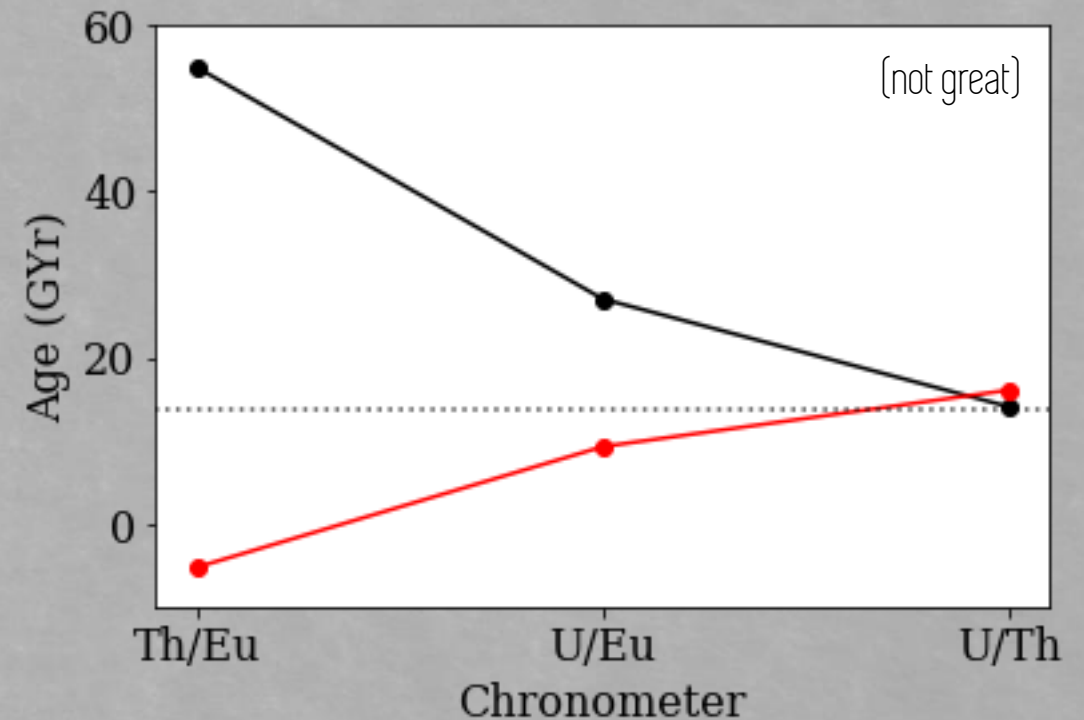


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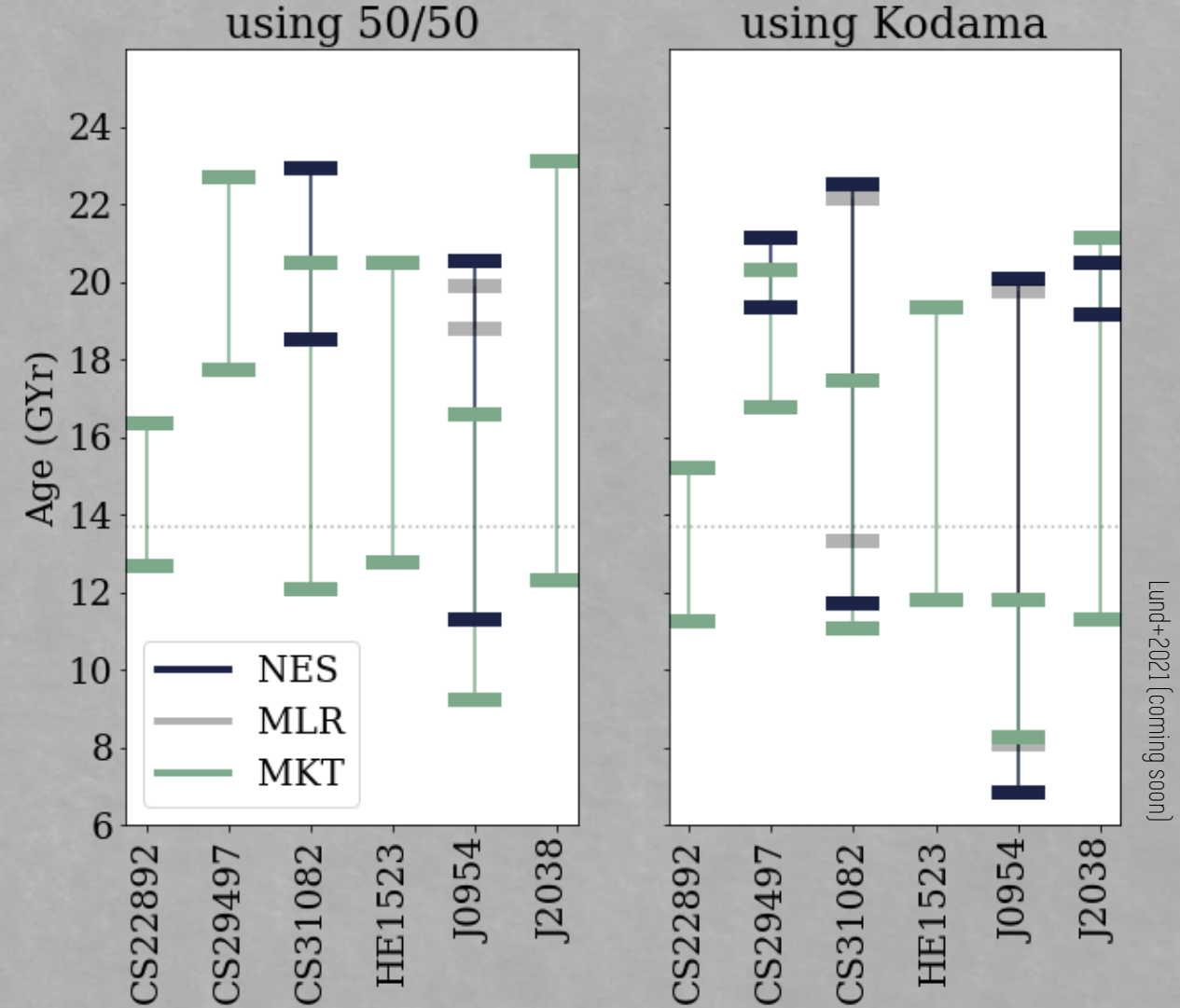
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Range of age estimates obtained by combining error bars from observations and uncertainties from theory  
 -BUT-  
 requiring that values agree to within 2GYr



Lund+2021 (coming soon)

Thank you!

Questions?

