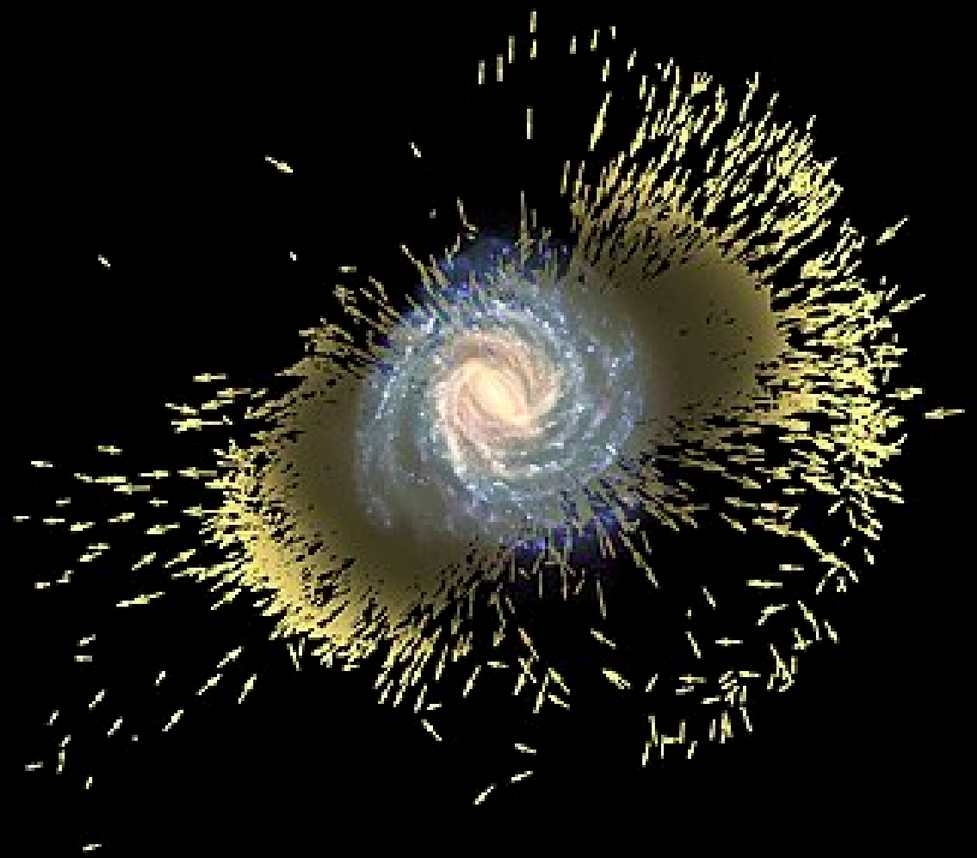

PRODUCTION OF RAPID NEUTRON-CAPTURE PROCESS (R-PROCESS) ELEMENTS IN THE COLLISION OF THE MILKY WAY WITH THE GAIA-SAUSAGE.

Diana Carolina Zapata Zuluaga

UNIVERSIDAD DE ANTIOQUIA
Facultad de Enfermería

Supervisor: Dr. David Aguado

INSTITUTO DE ASTROFÍSICA DE CANARIAS · IAC

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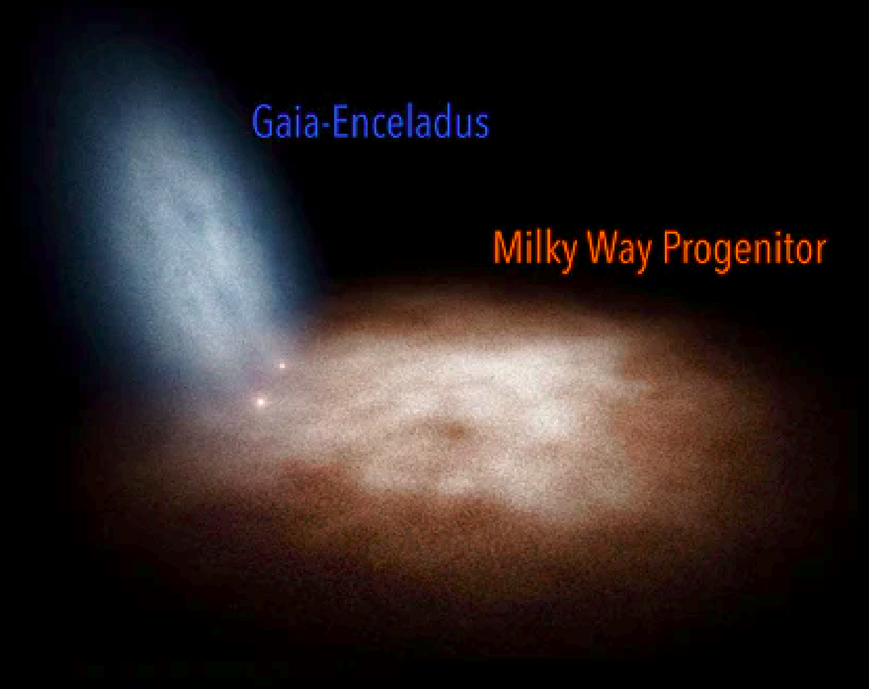
ASTRO FEST 24

1

Gaia - Sausage

1

Gaia - Sausage



https://spaceaustralia.com.au/blogs/news/gaia-sausage-older-than-grandpa-stars-astronomers-find

~ 10 billion years ago

~ 10% of the mass of the Milky Way

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1

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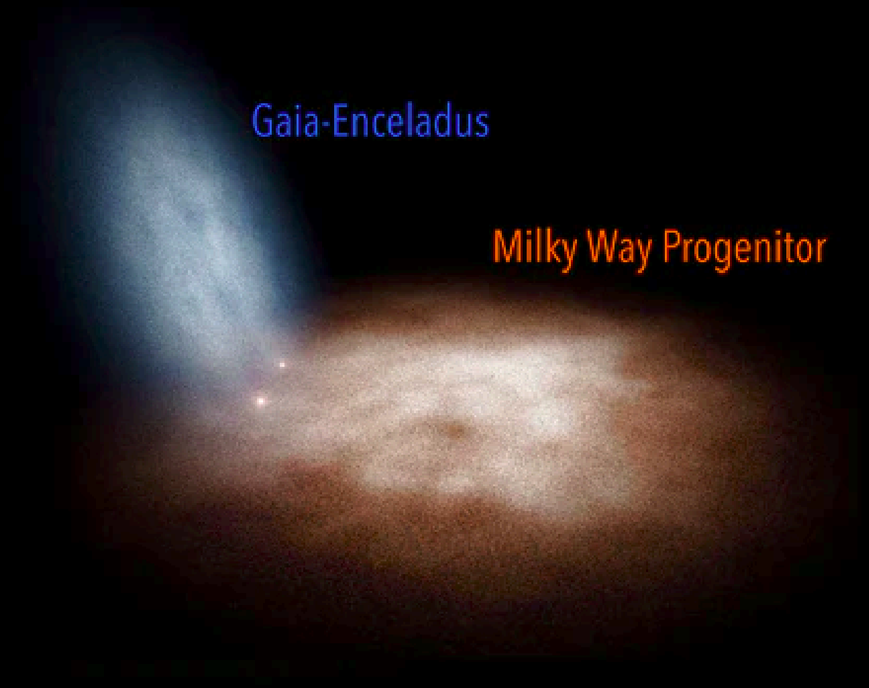

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Sequoia

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1

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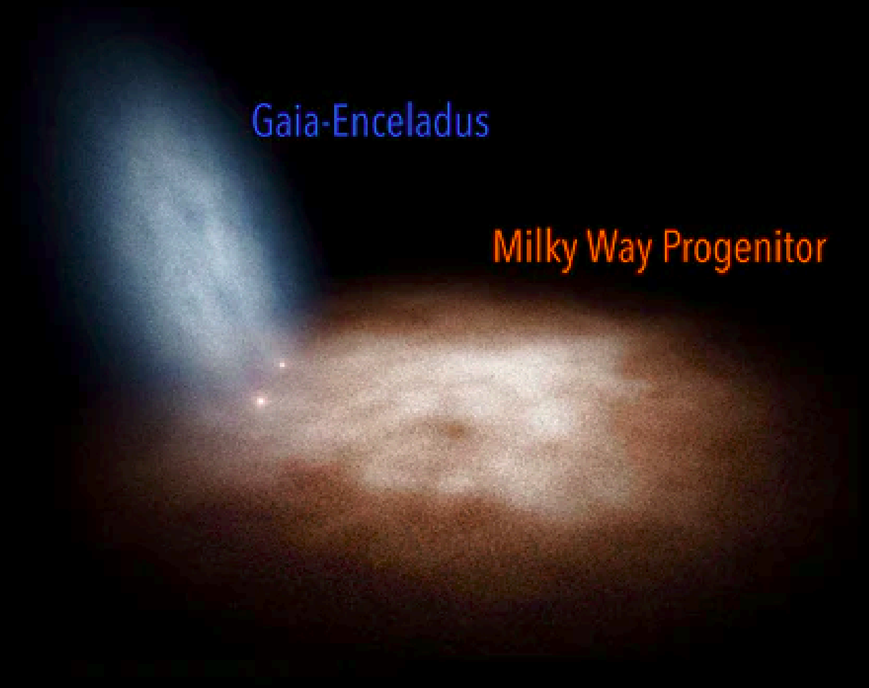

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Sequoia

- The Milky Way's halo is formed largely from small accreted systems like Gaia Sausage and Sequoia.

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1

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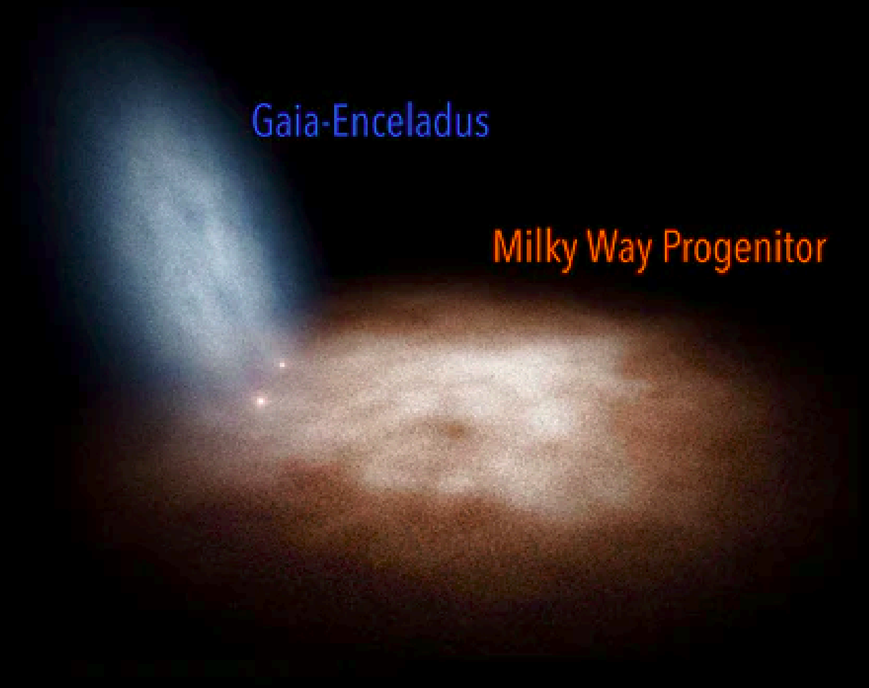

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~ 10 billion years ago

~ 10% of the mass of the Milky Way

Sequoia

- The Milky Way's halo is formed largely from small accreted systems like Gaia Sausage and Sequoia.
- Their stars are like fossils, allowing us to study chemical evolution.

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Neutron-capture elements

Neutron-capture elements

Sr, Y, Ba and Eu

Neutron-capture elements

Sr, Y, Ba and Eu

R-process (rapid)

S-process (slow)

Neutron-capture elements

Sr, Y, Ba and Eu

R-process (rapid)

?

Neutron-capture elements

Sr, Y, Ba and Eu

R-process (rapid)

Neutron Star Mergers (NSM)

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Sr, Y, Ba and Eu

R-process (rapid)

Neutron Star Mergers (NSM)

Type II Supernovae

Why is it important?

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- To better understand the origin of r-process elements
- To use chemical abundances to unravel the history of Gaia-Sausage and Sequoia

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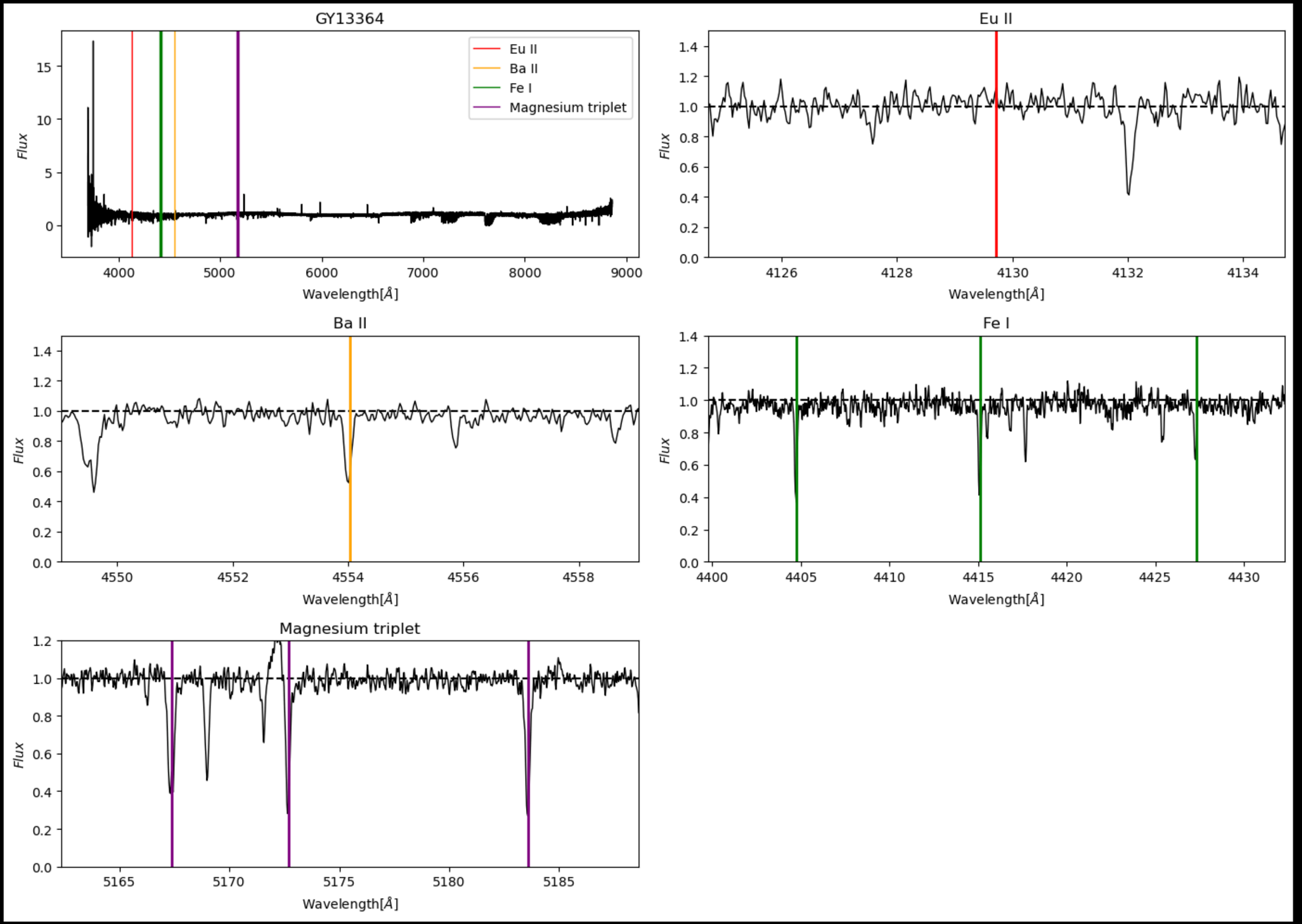
- To use chemical abundances to unravel the history of Gaia-Sausage and Sequoia

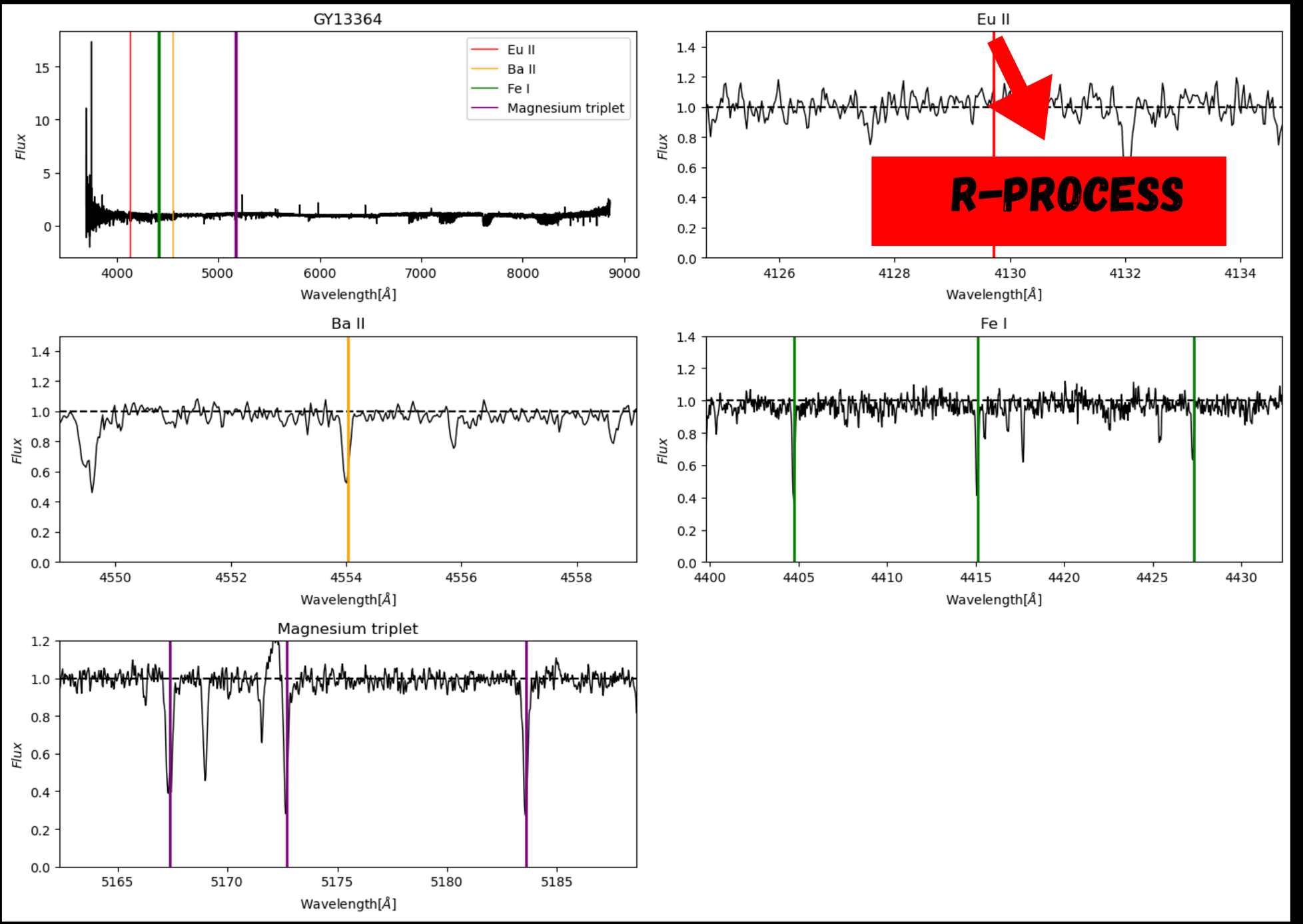
How is this done?

1. Seven stars from Sequoia and Gaia Sausage were obtained, observed with the FIES spectrograph

4


GY13364
Eu II
Ba II
Fe I
Magnesium triplet
Flux
Wavelength[Å]
Eu II
Ba II
Fe I
Magnesium triplet

4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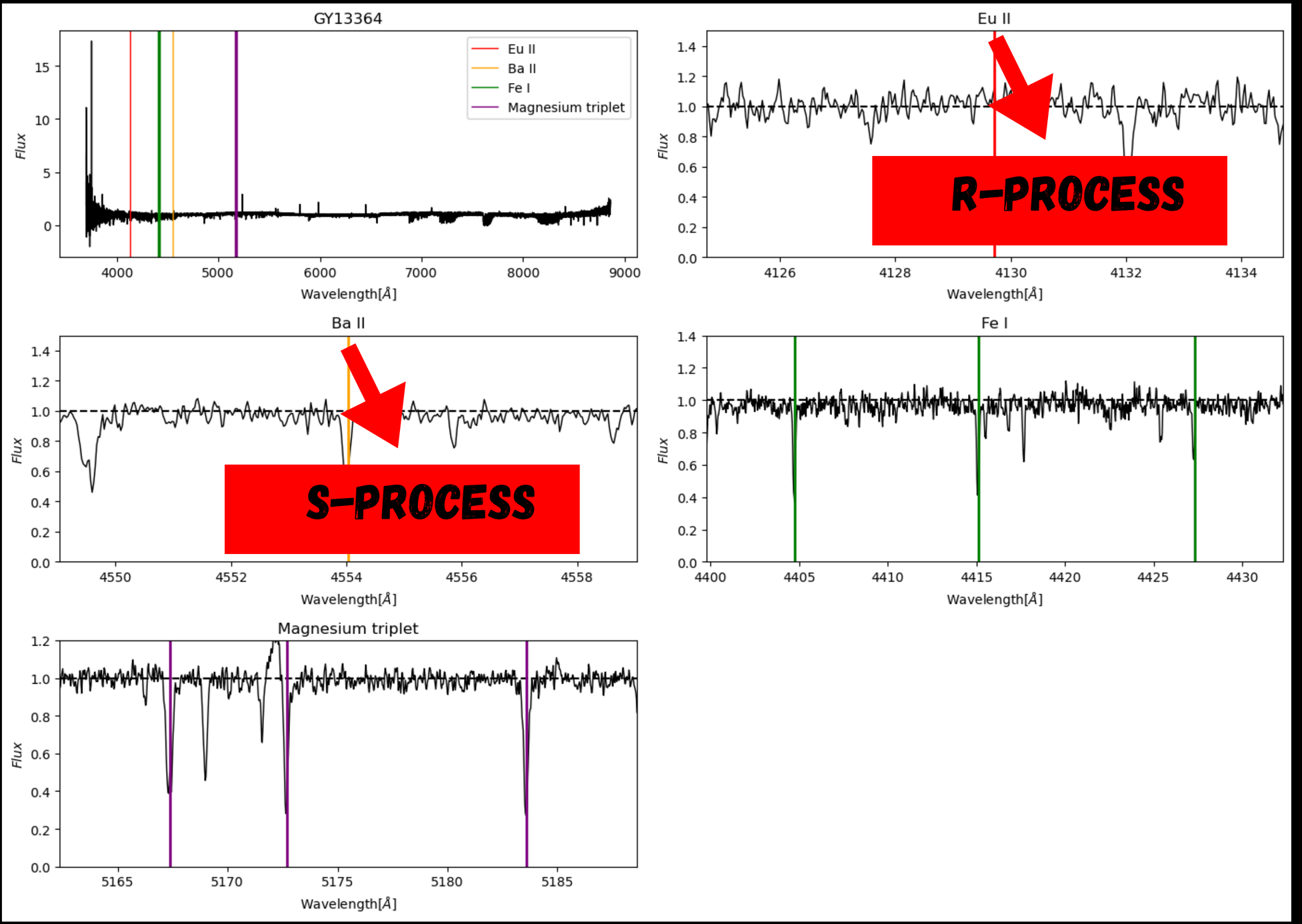
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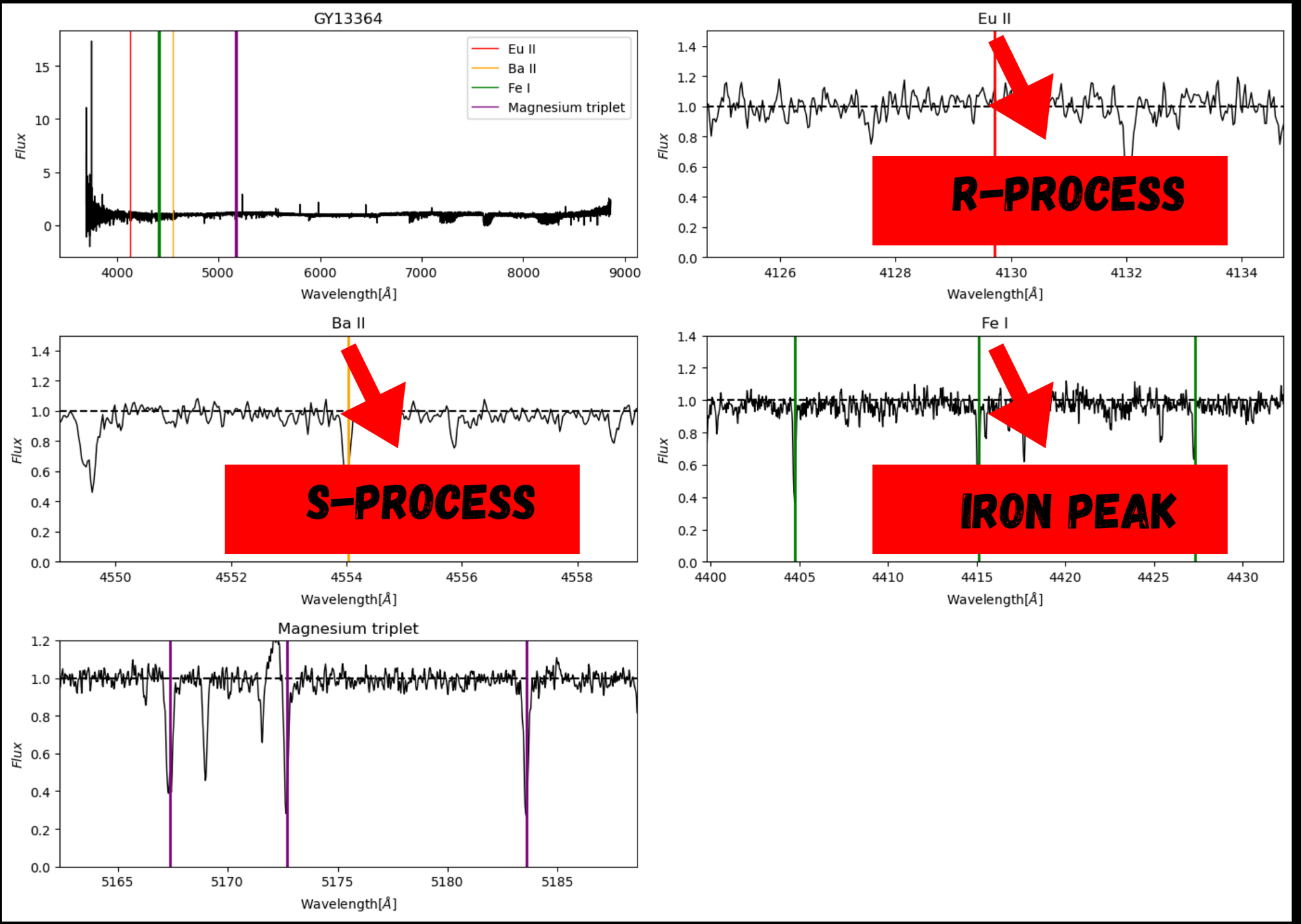
GY13364
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Eu II
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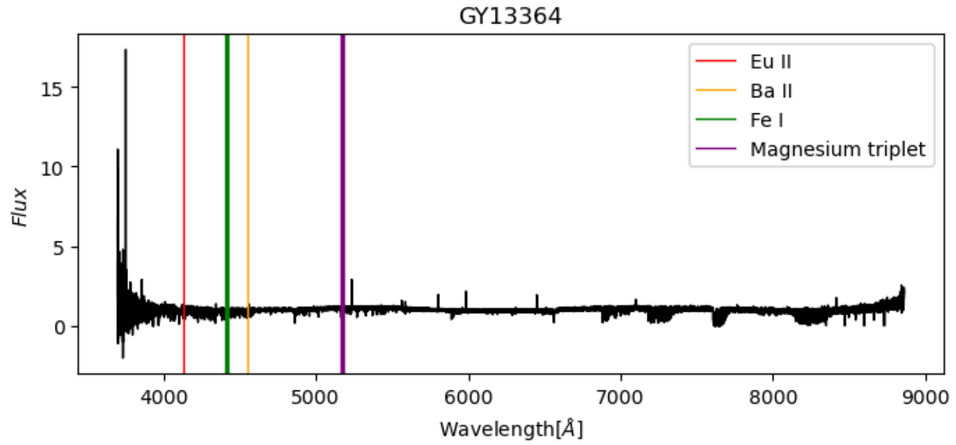
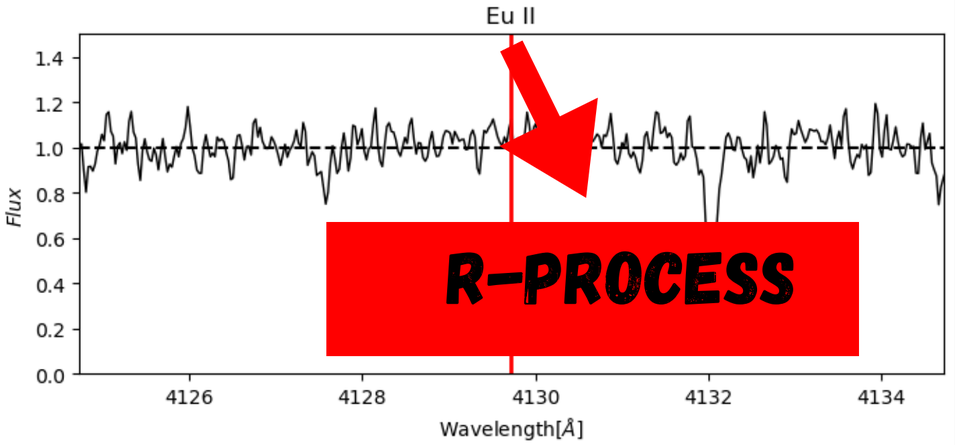
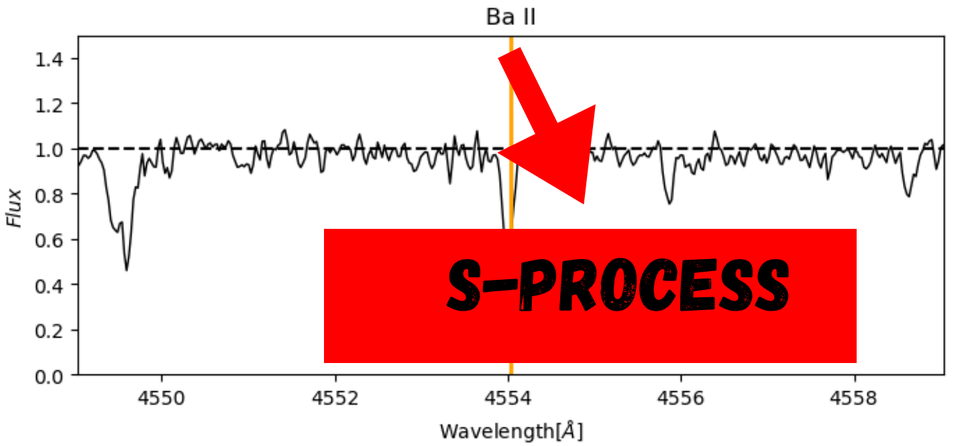
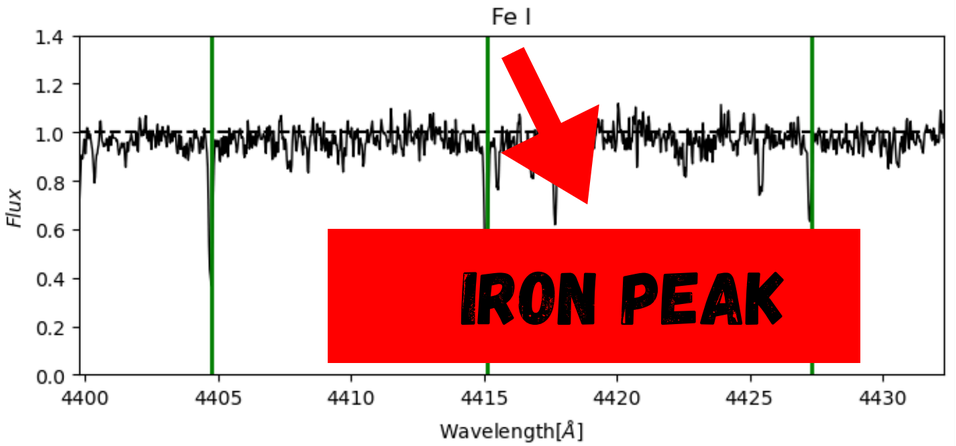
Fe I
IRON PEAK
Magnesium triplet

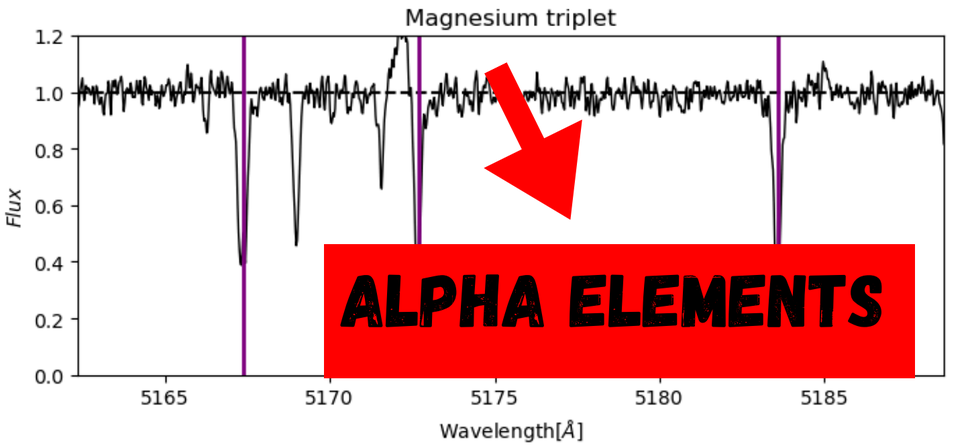
4


GY13364
Eu II
Ba II
Fe I
Magnesium triplet
Flux
Wavelength[Å]

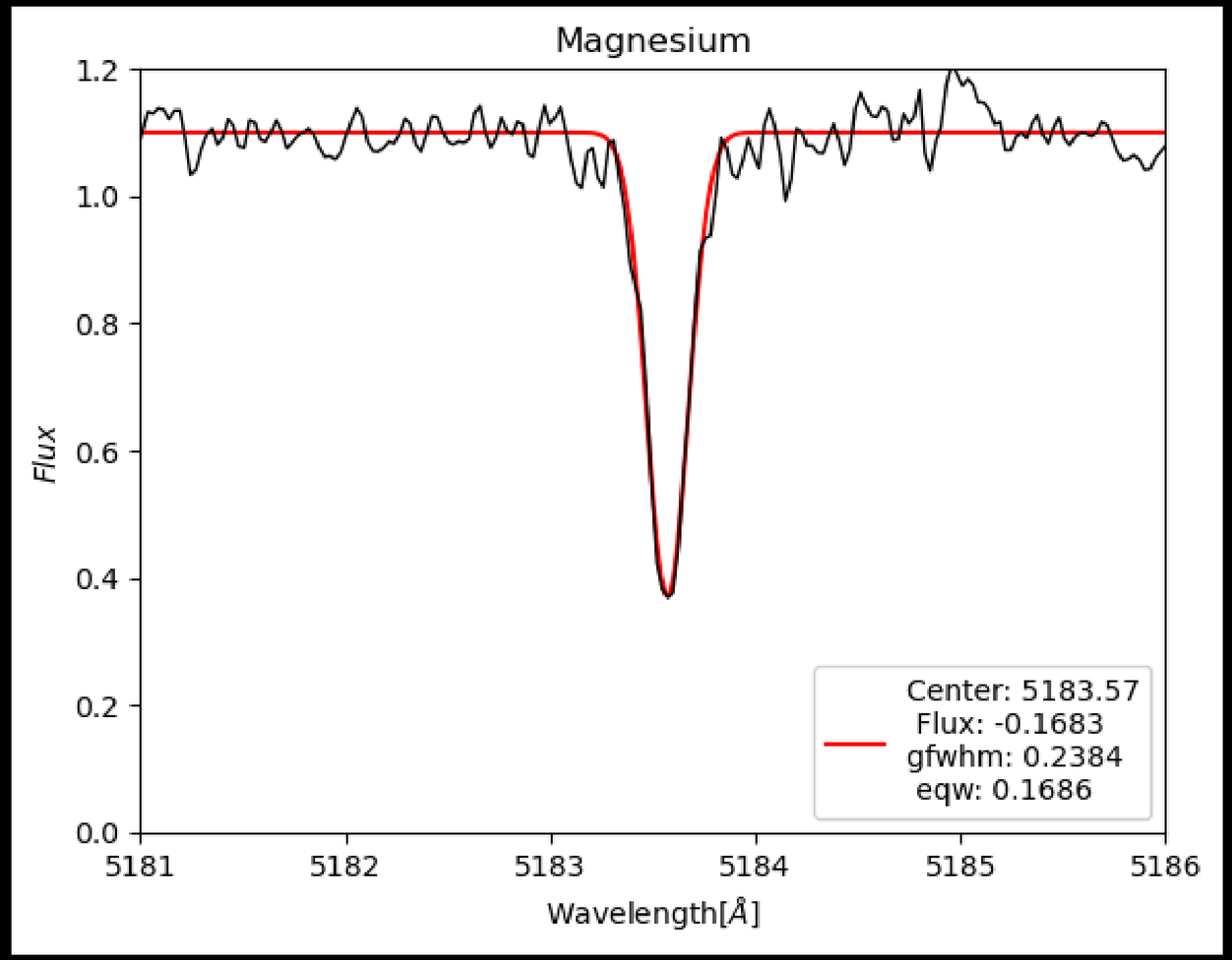

Eu II
R-PROCESS
Flux
Wavelength[Å]


Ba II
S-PROCESS
Flux
Wavelength[Å]


Fe I
IRON PEAK
Flux
Wavelength[Å]


Magnesium triplet
ALPHA ELEMENTS
Flux
Wavelength[Å]

5



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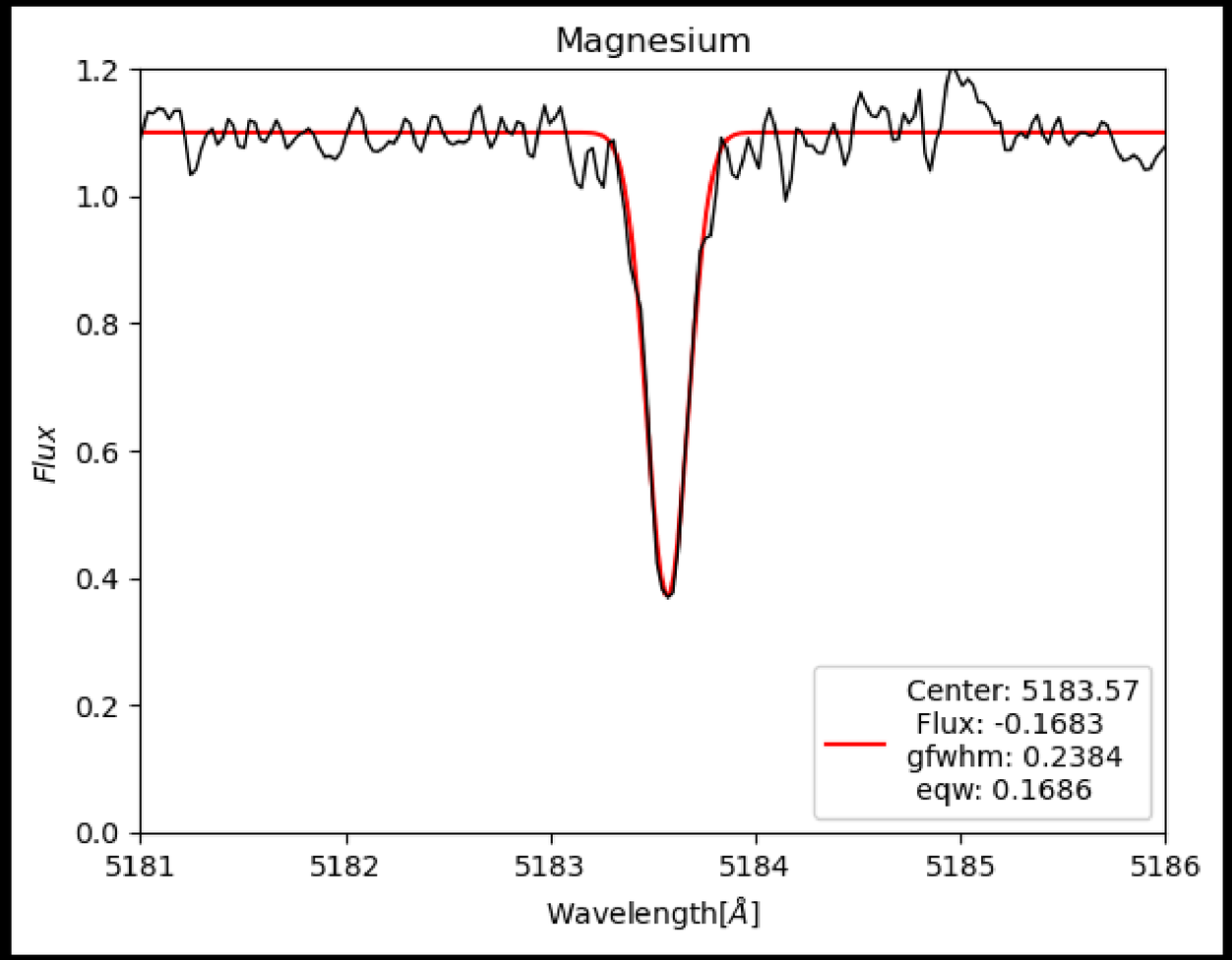

MOOG

#Wavelength	ele	EP	loggf	EQ
5183.6042	12.0	2.72	-0.167	168.600

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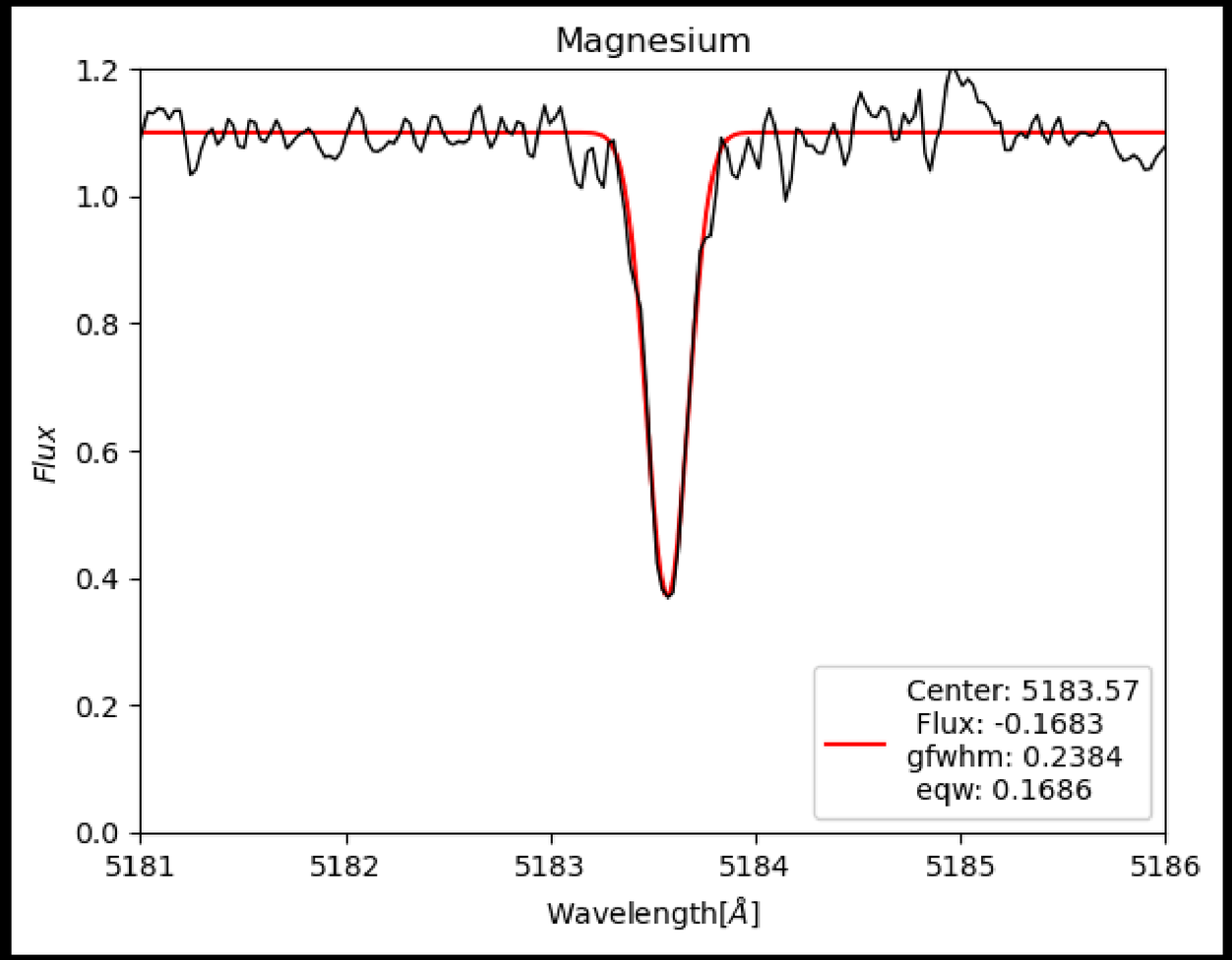

MOOG

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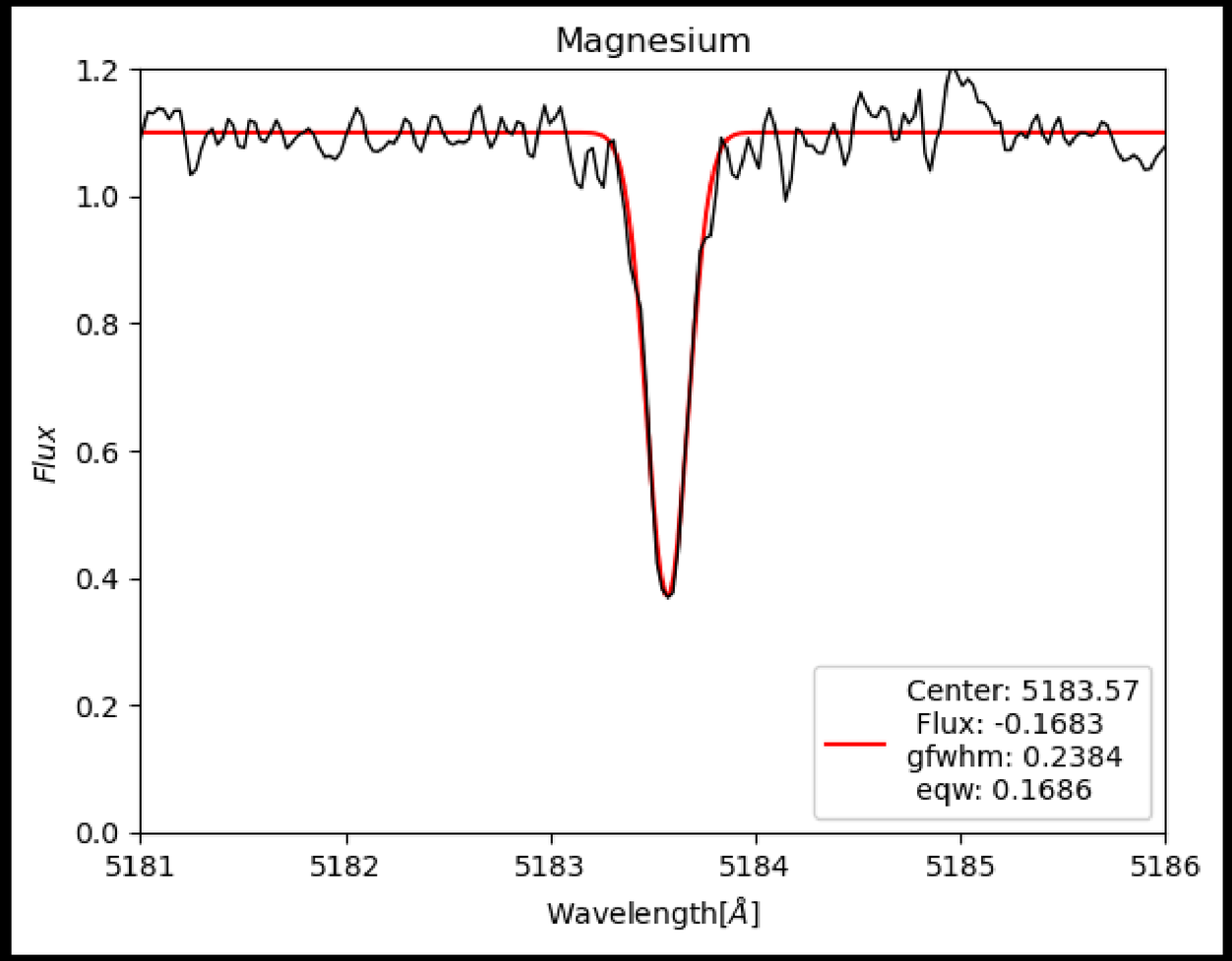
Atmospheric models with ATLAS9

- Radiative equilibrium
- Generates 1-D models

5



30 Fe lines
Three Mg lines (Magnesium Triplet)
1-4 Ba and Eu lin

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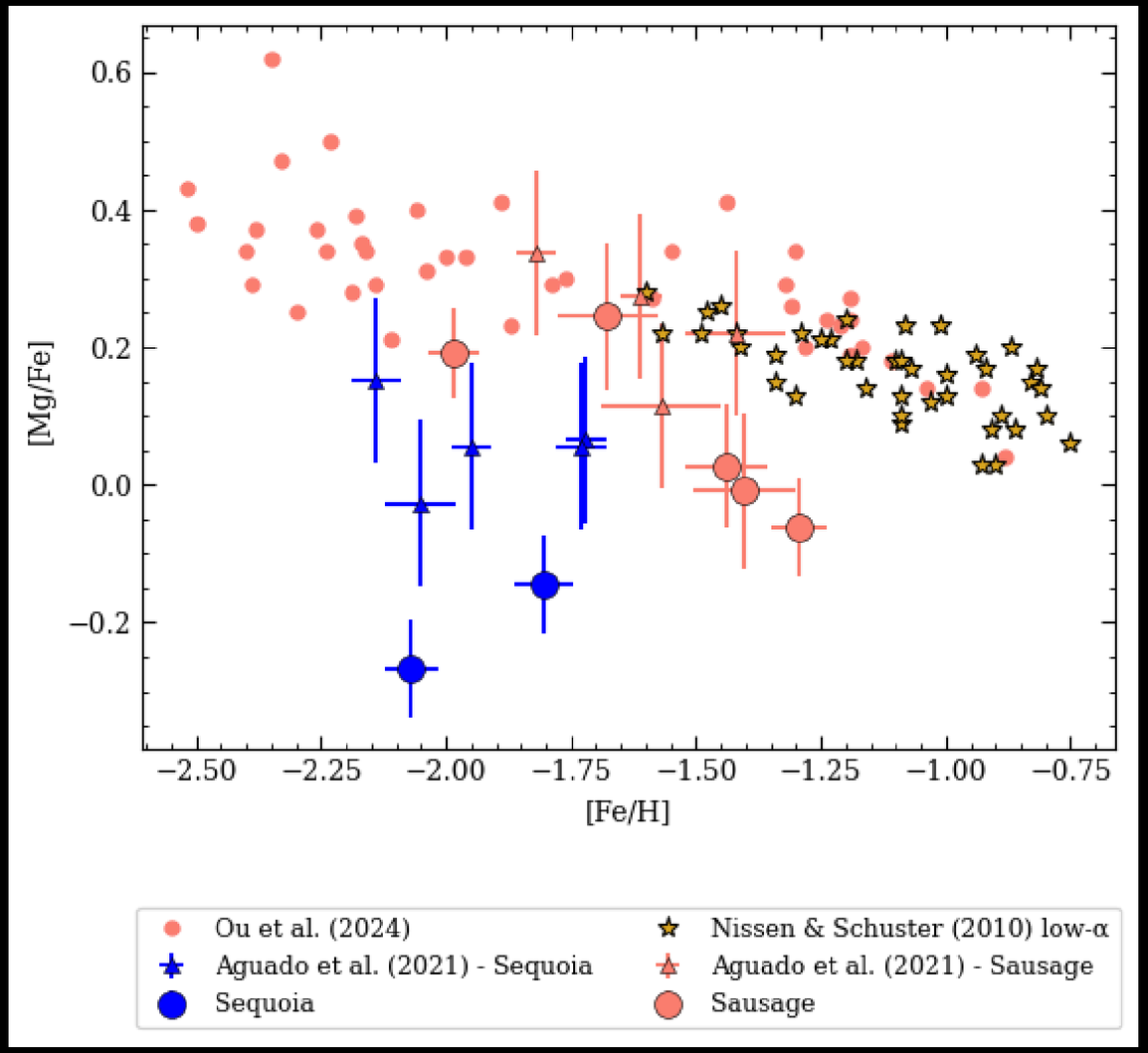
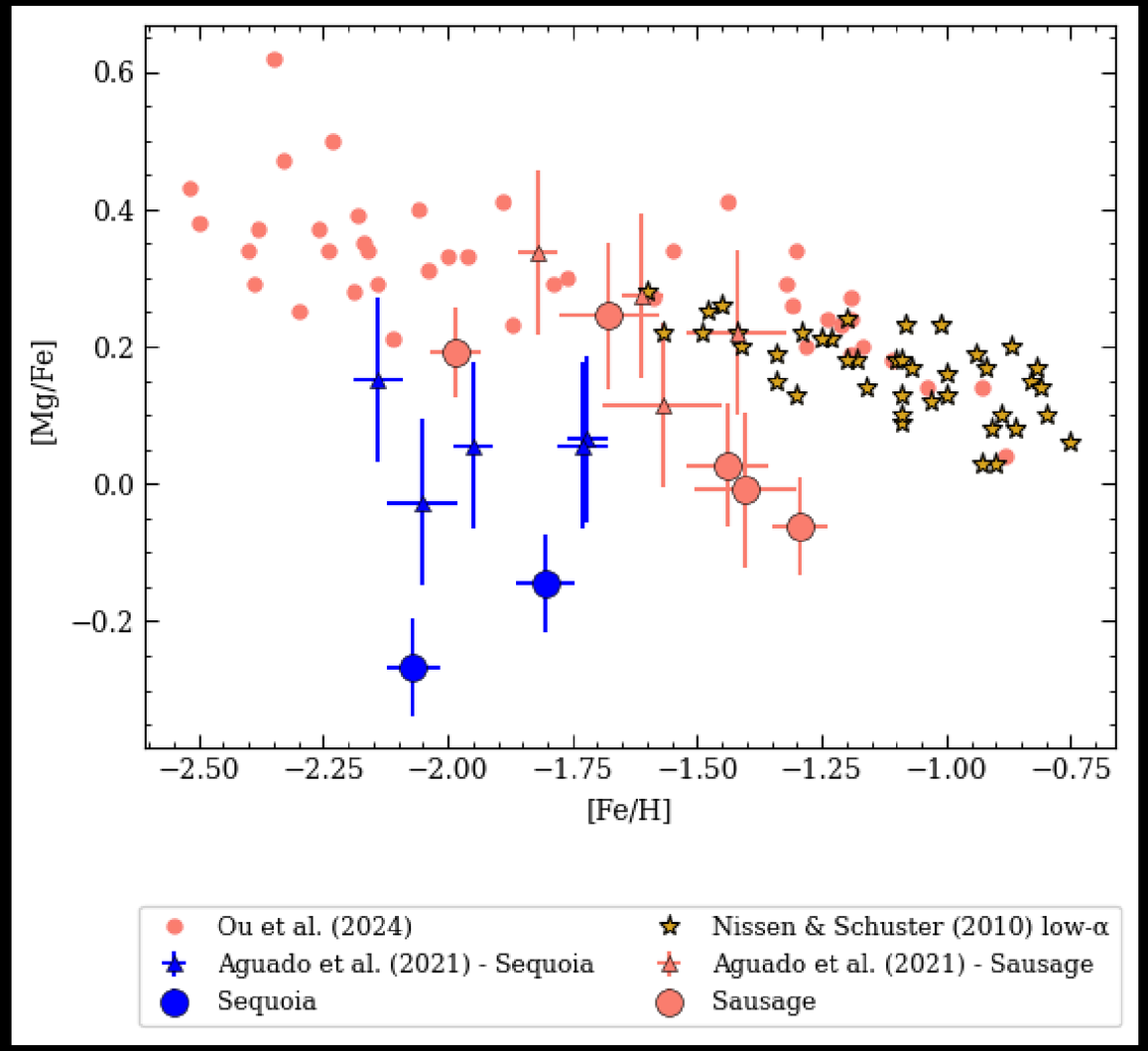
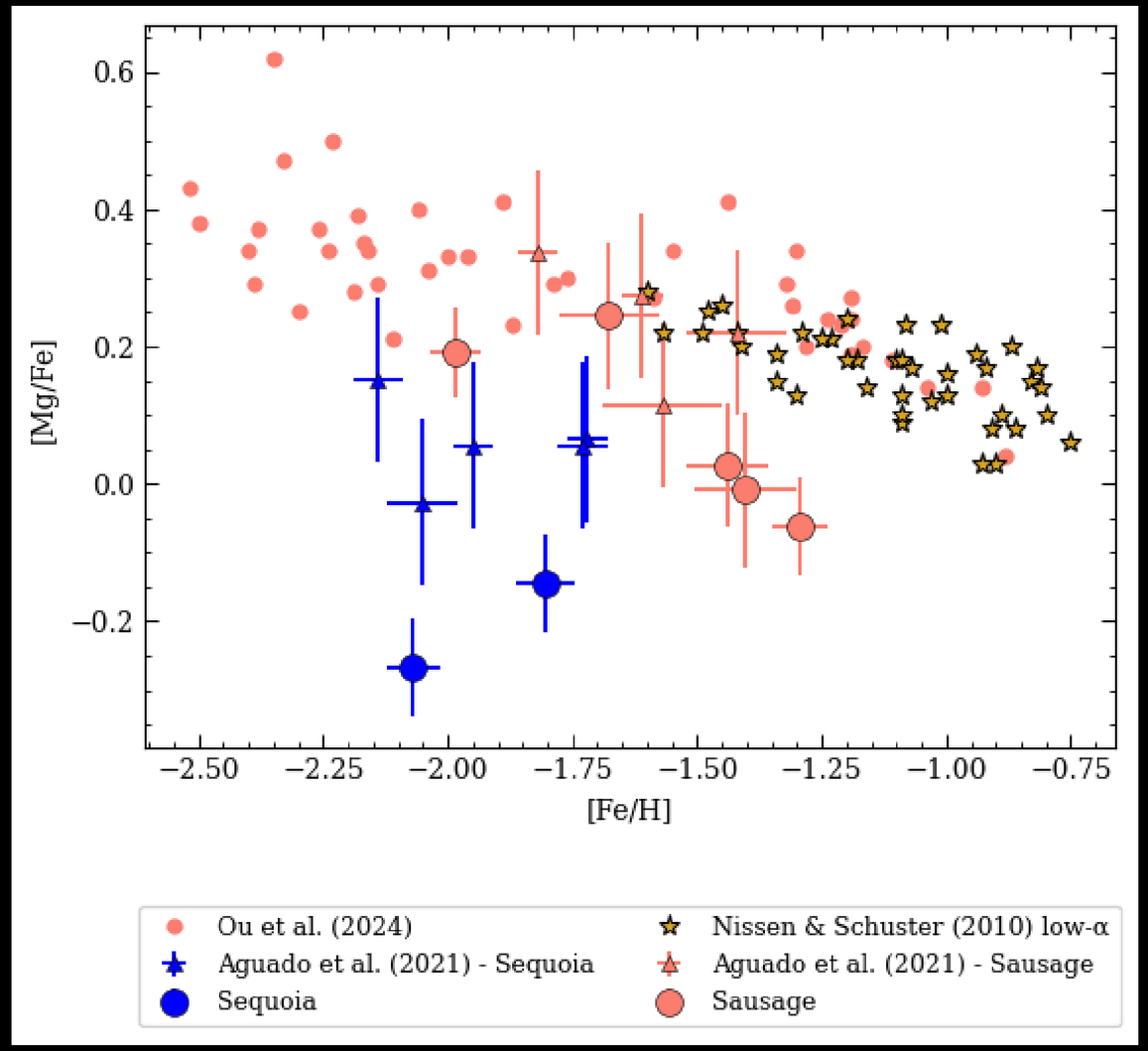
6



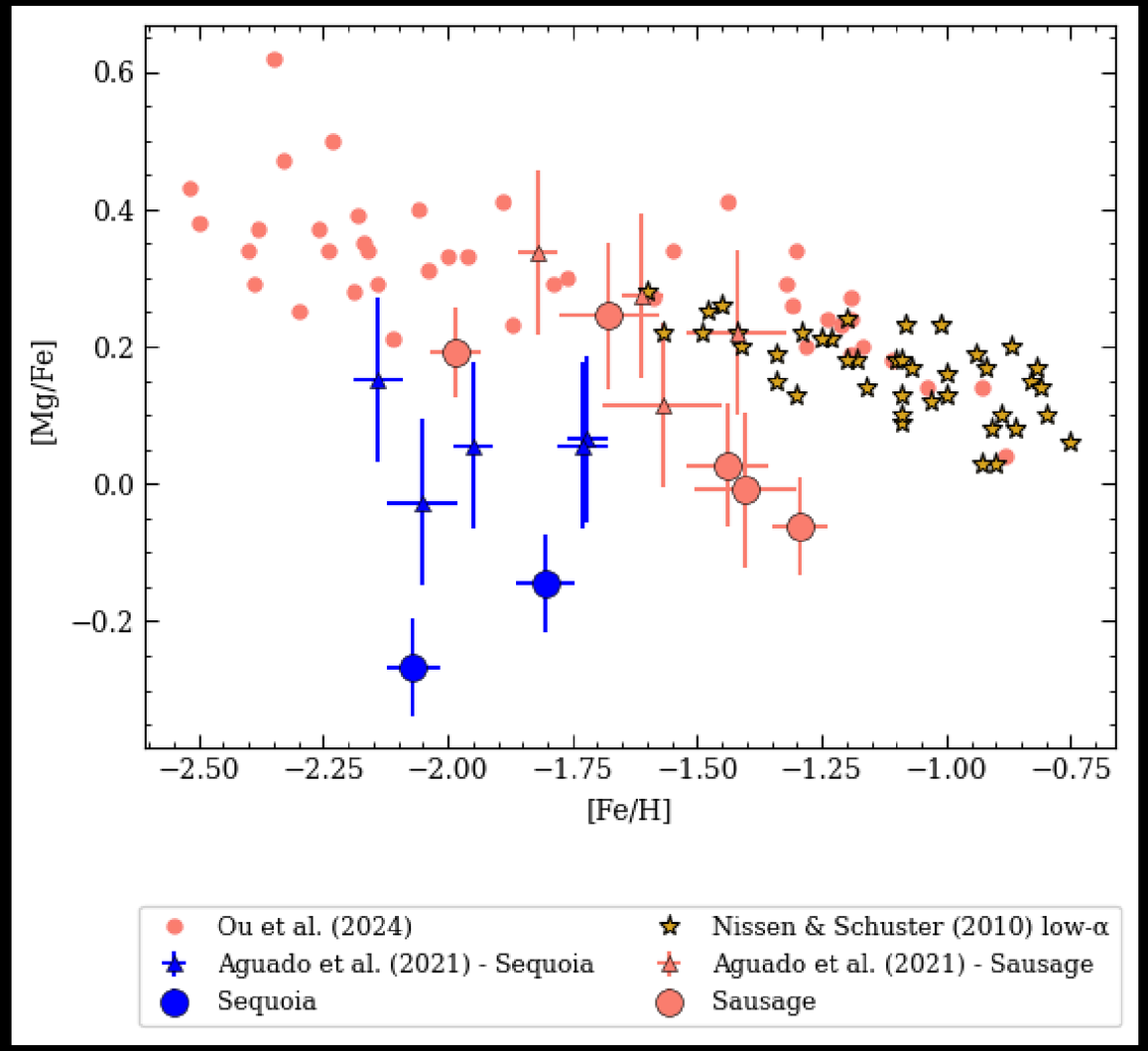


More massive stars die ---> Type II Supernovae



More massive stars die ---> Type II Supernovae

Less massive stars die ---> Type Ia Supernovae



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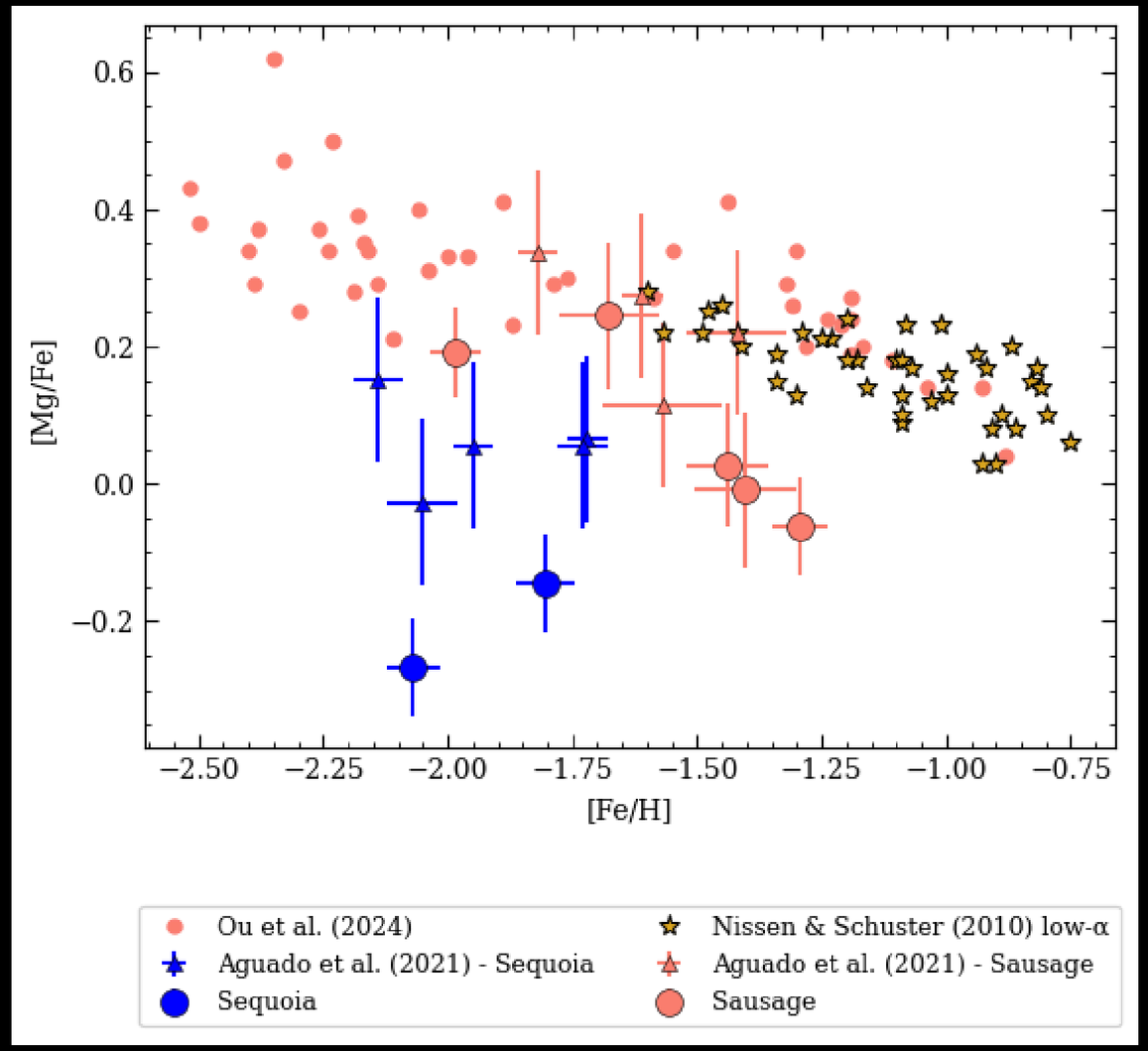
Alpha-knee

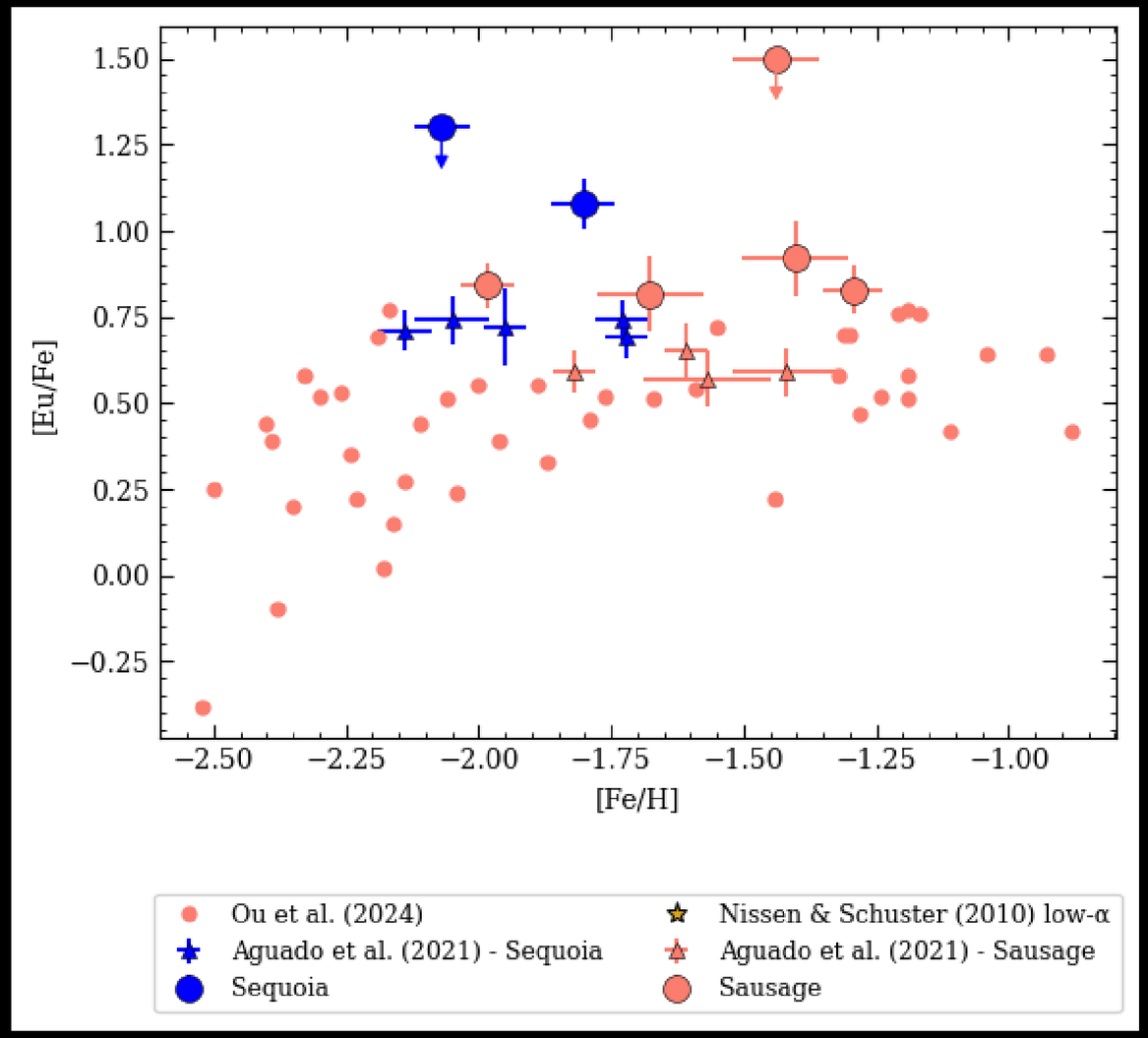


More massive stars die ---> Type II Supernovae

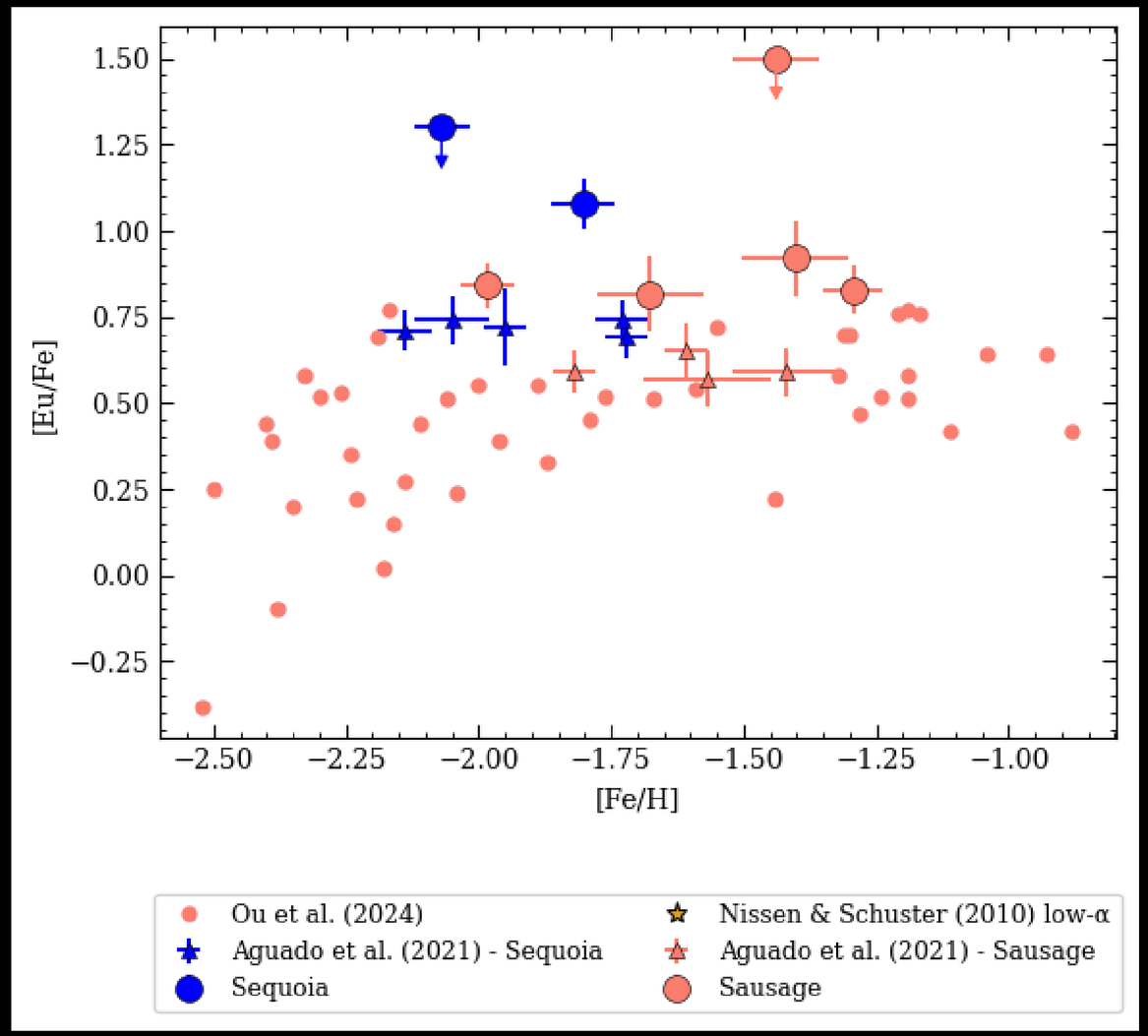
Less massive stars die ---> Type Ia Supernovae

Alpha-knee

Sequoia --> Low metallicities
Gaia Sausage --> High metallicities



High dispersion



High dispersion --> Delay in the production of Eu

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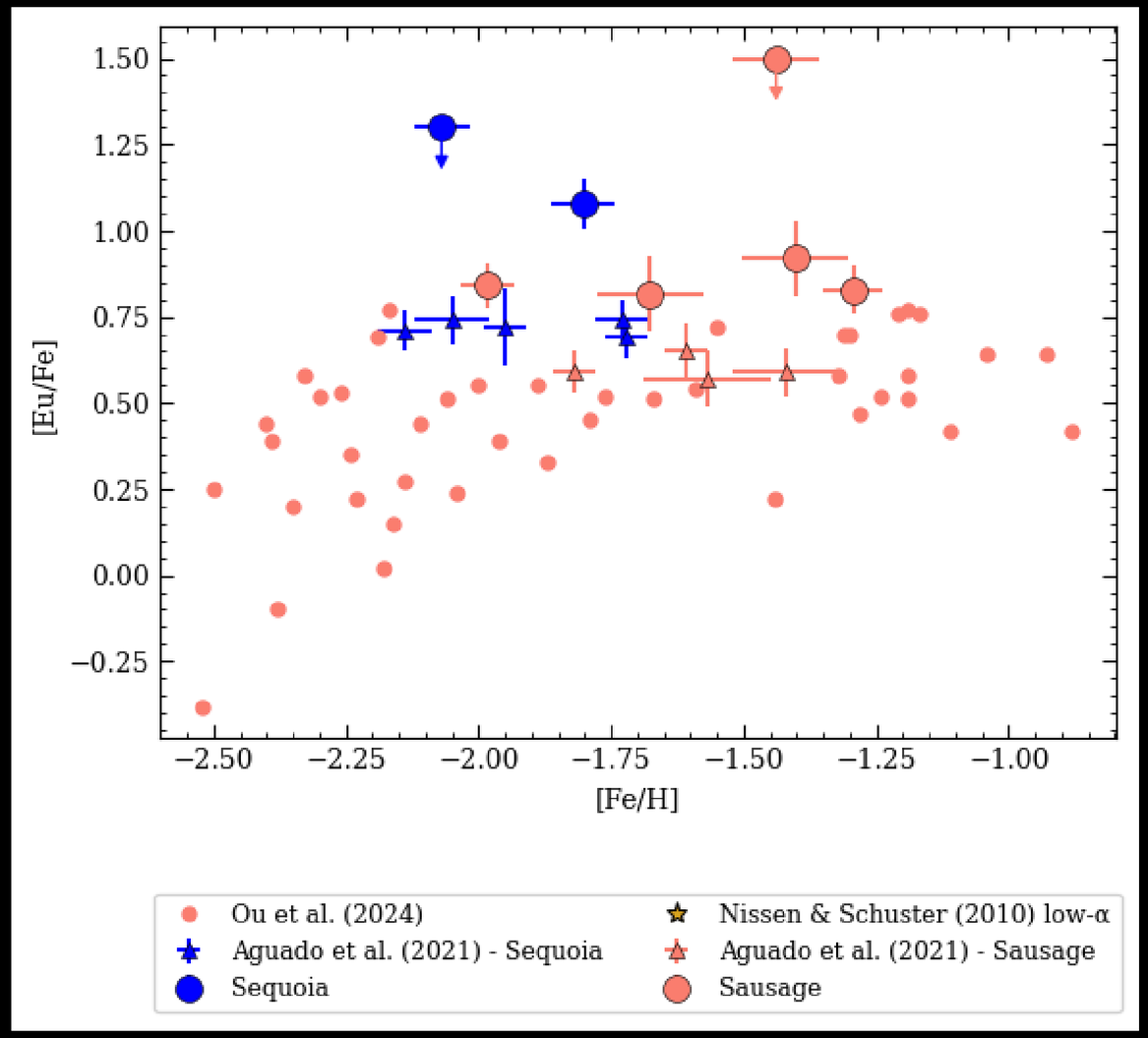

High dispersion --> Delay in the production of Eu

NSM

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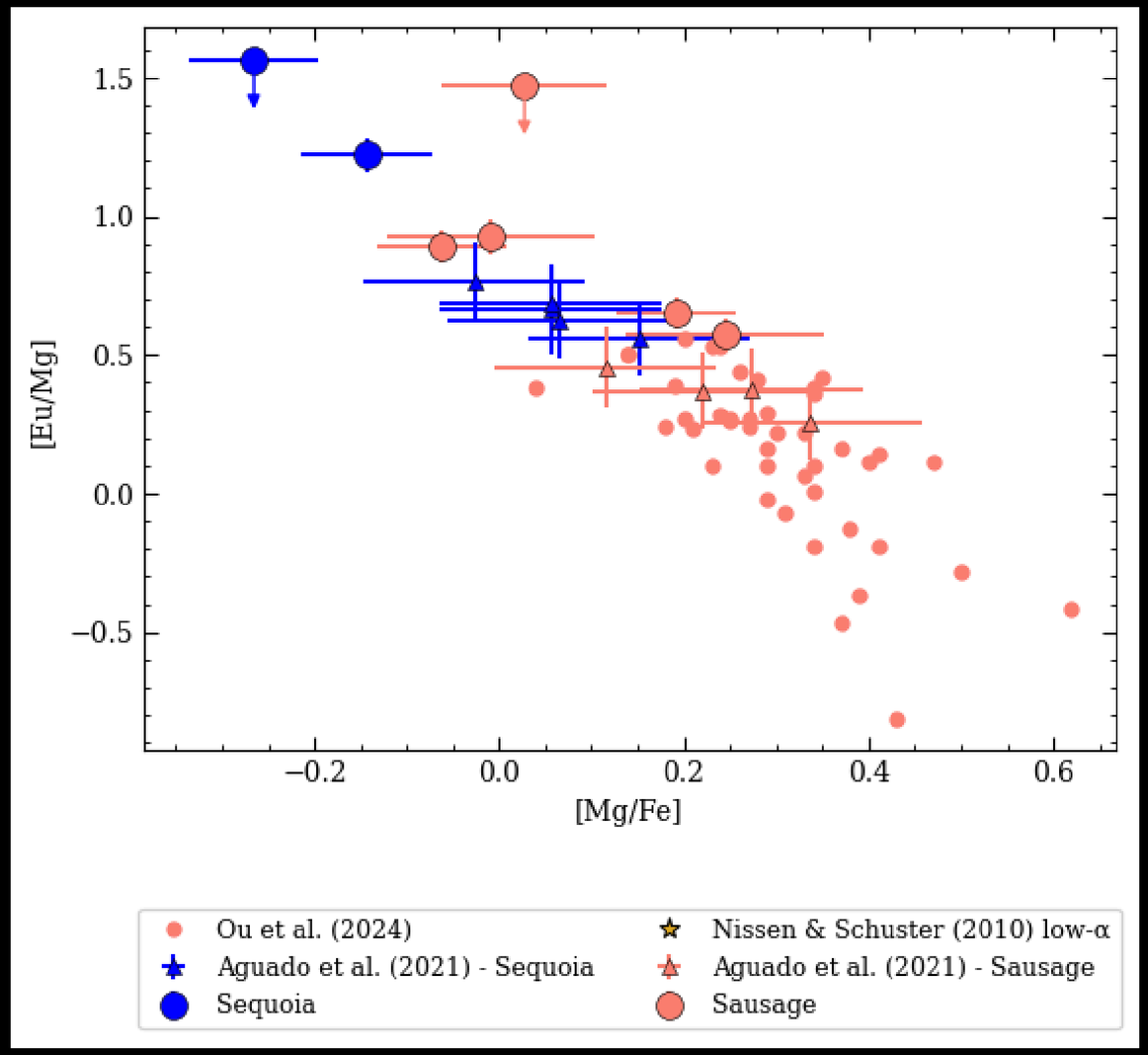
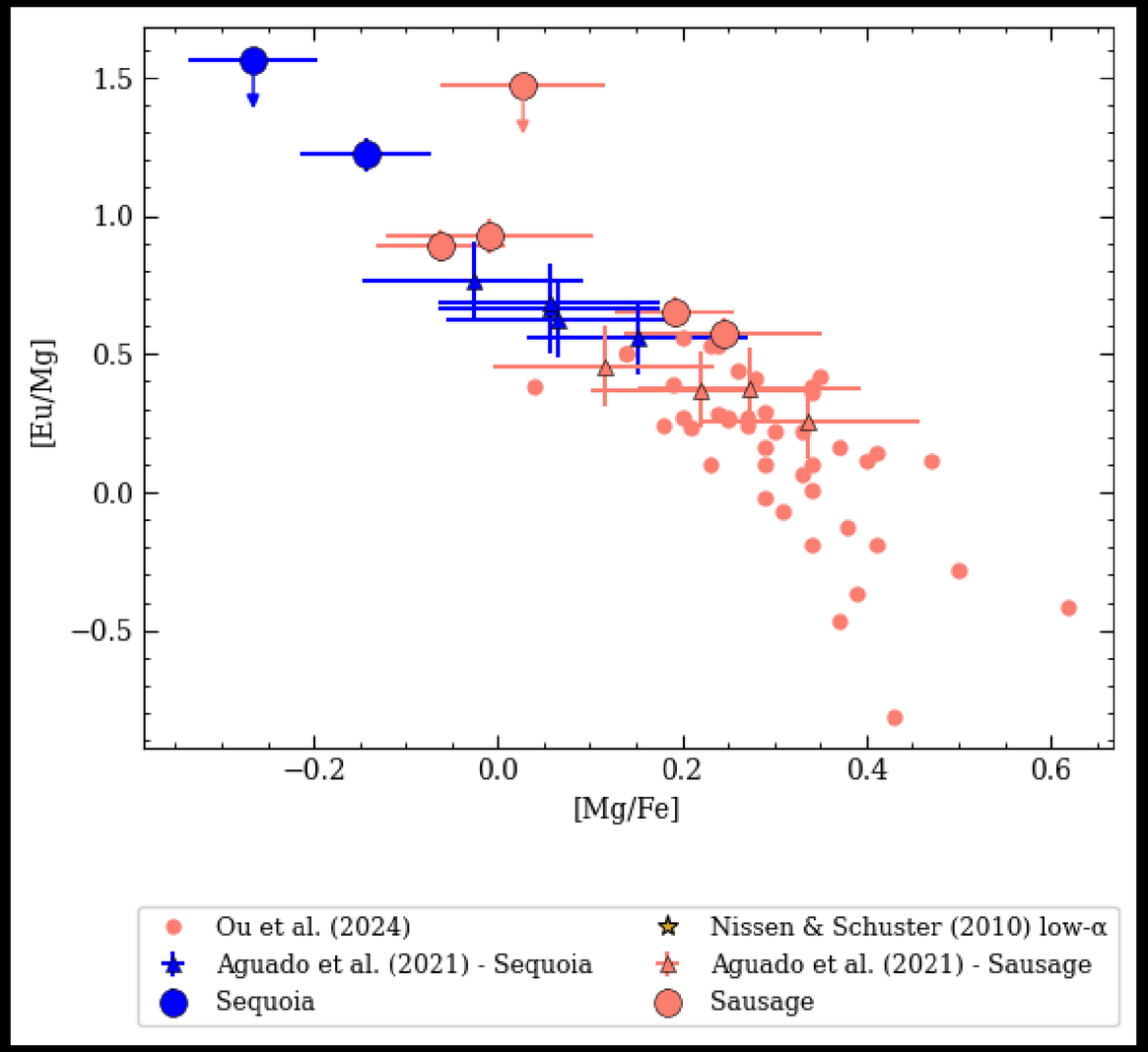
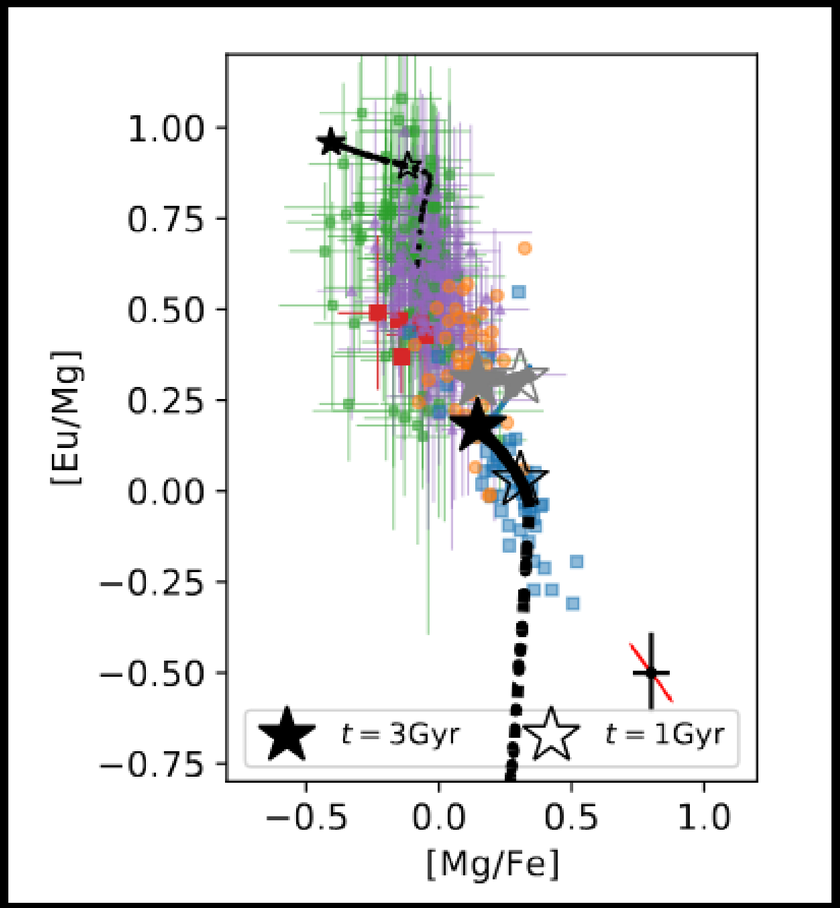
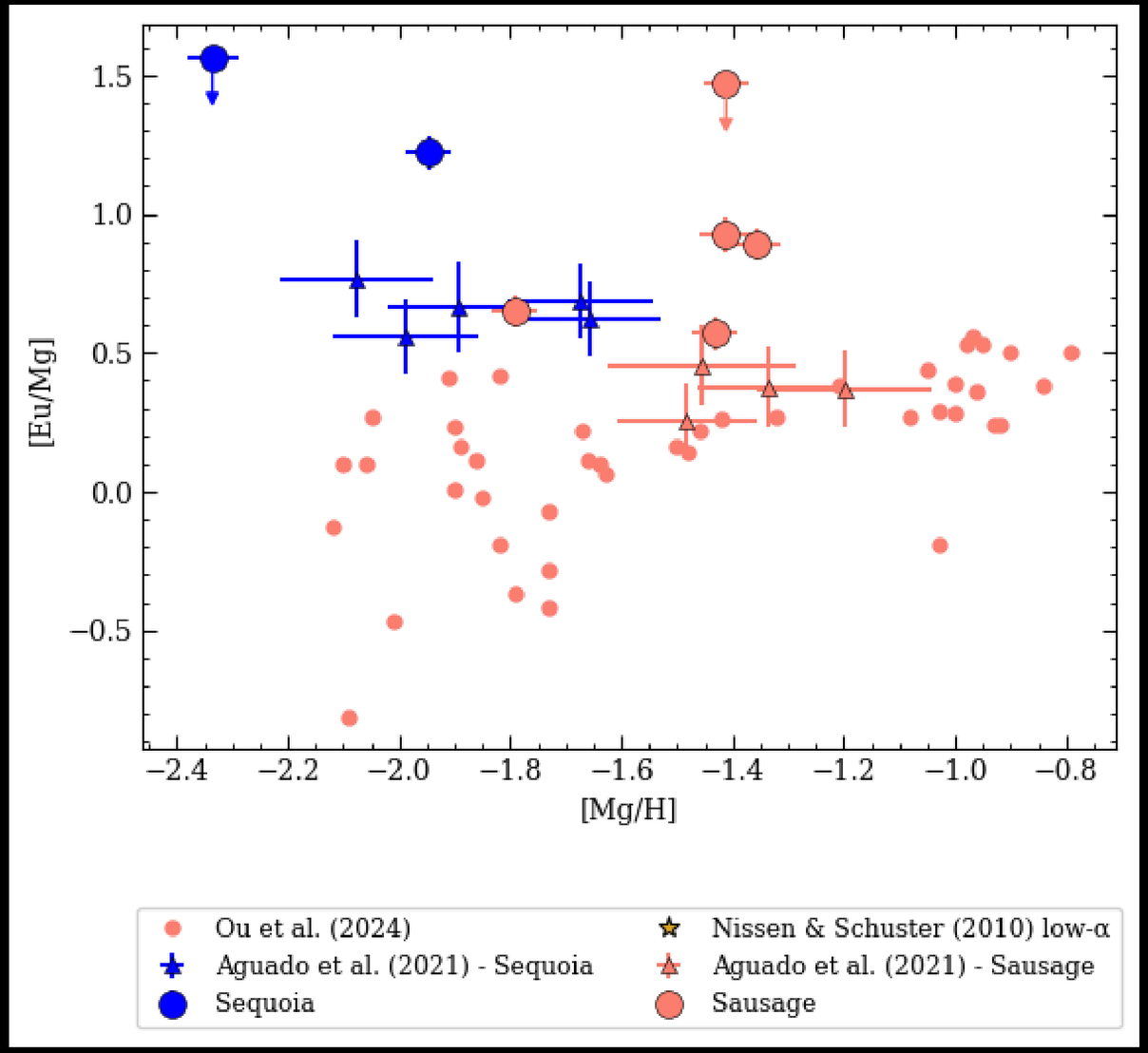

1.5
1.0
0.5
0.0
−0.5
[Eu/Mg]
−0.2
0.0
0.2
0.4
0.6
[Mg/Fe]
Ou et al. (2024)
Aguado et al. (2021) - Sequoia
Sequoia
Nissen & Schuster (2010) low-α
Aguado et al. (2021) - Sausage
Sausage





T. Matsuno et al.: R-process enhancements of Gaia-Enceladus in GALAH DR3


1.5
1.0
0.5
0.0
−0.5
[Eu/Mg]
−2.4
−2.2
−2.0
−1.8
−1.6
−1.4
−1.2
−1.0
−0.8
[Mg/H]
Ou et al. (2024)
Aguado et al. (2021) - Sequoia
Sequoia
Nissen & Schuster (2010) low-α
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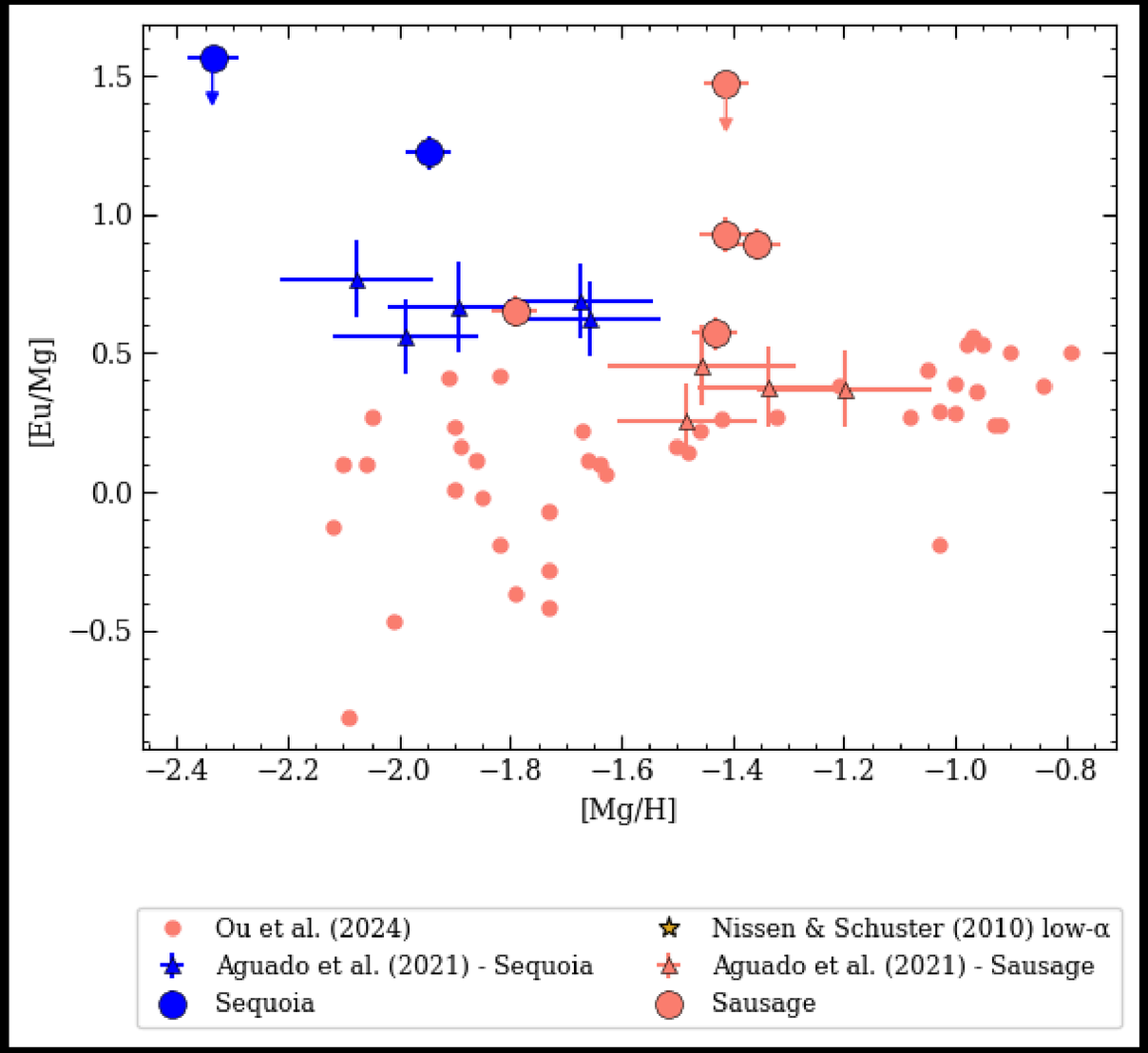
Sausage



This upward trend is strong evidence of the presence of r-process sources that act with a delay, presumably NSM.

Conclusions

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- NSMs are likely required to explain the production of r-process elements in Gaia Sausage.
- To better understand Sequoia, we would need to explore stars with even lower metallicity.

Future work

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- Acquire more observational data on stars, particularly those with the lowest possible metallicity.

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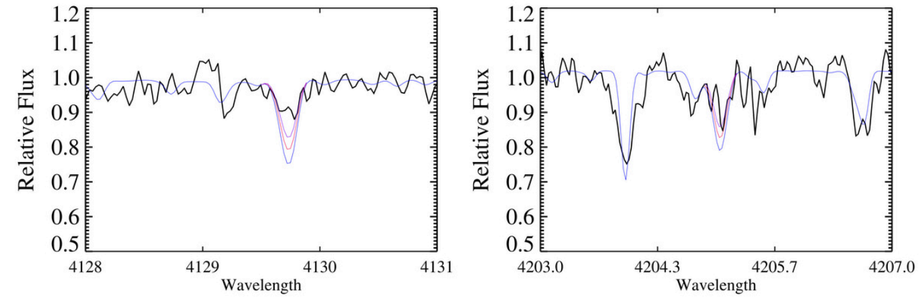
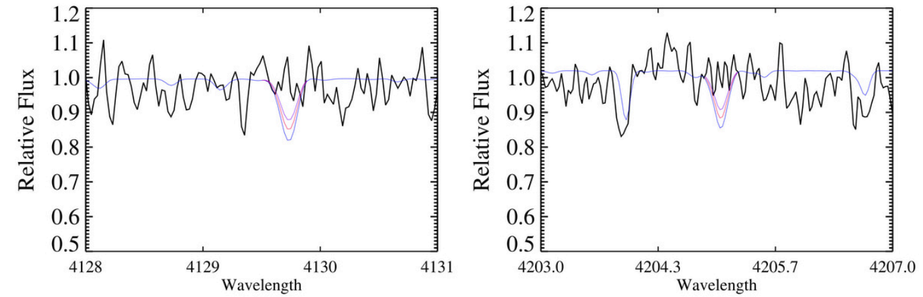
- Acquire more observational data on stars, particularly those with the lowest possible metallicity.
- Use theoretical models to validate and further understand the evolution we have observed.

Acknowledgments

- Supervisor: Dr. David Aguado.
- RECA Internship 2024.
- Xiaowei Ou, author of the work that we used to complement our data



GY45001 [Fe/H]=-1.67
Teff=6514 K logg=5.0
[Eu/Fe]=+1.5
[Eu/Fe]=+1.40
[Eu/Fe]=+1.30



GY13364 [Fe/H]=-2.30
Teff=6116 K logg=3.95
[Eu/Fe]=+1.5
[Eu/Fe]=+1.40
[Eu/Fe]=+1.30