High-dispersion spectroscopic observations of r-process elements including thorium in solar metallicity and mildly-metal-poor stars

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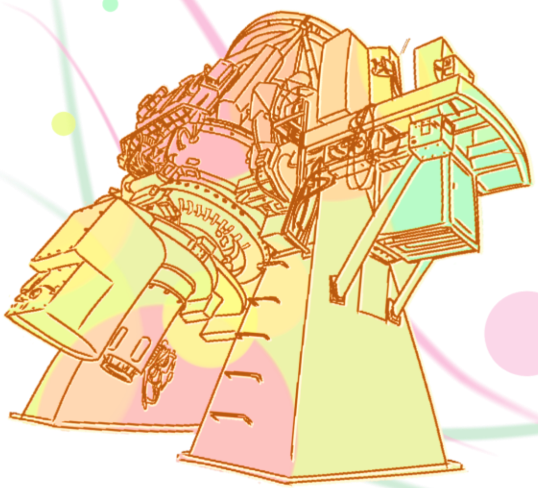
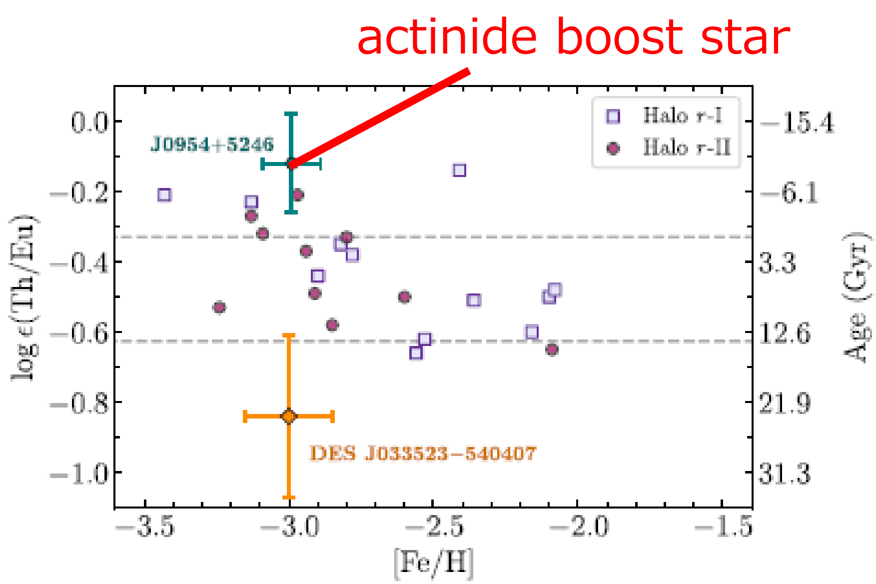


The origin of r-process and Th Observation

Recently Neutron Star Merger (NSM) is consider the origin of r-process.
Tanaka et al., 2017, Watson et al., 2019

Although there are stars which have more Th(Thorium) abundance than other r-process elements (actinide boost star). These stars indicate r-process have more than one origin.(e.g. magneto-rotational supernovae Nishimura et al., 2017, Yong et al., 2021)

Stellar atmosphere retains the result of nucleosynthesis in the universe. To clear the origin of r-process, we need to observe Th **in -2 ≲ [Fe/H].** Because the region has not been fully investigated.



(fig.1)Observed stellar abundance of log ε(Th/Eu) (Holmbeck et al., 2018).

$$[X/H] = \log\frac{(nX/nH)_{star}}{(nX/nH)_{\odot}}$$

log ε(Th/Eu)=log (n_{Th}/n_H) - log (n_{Eu}/n_H)

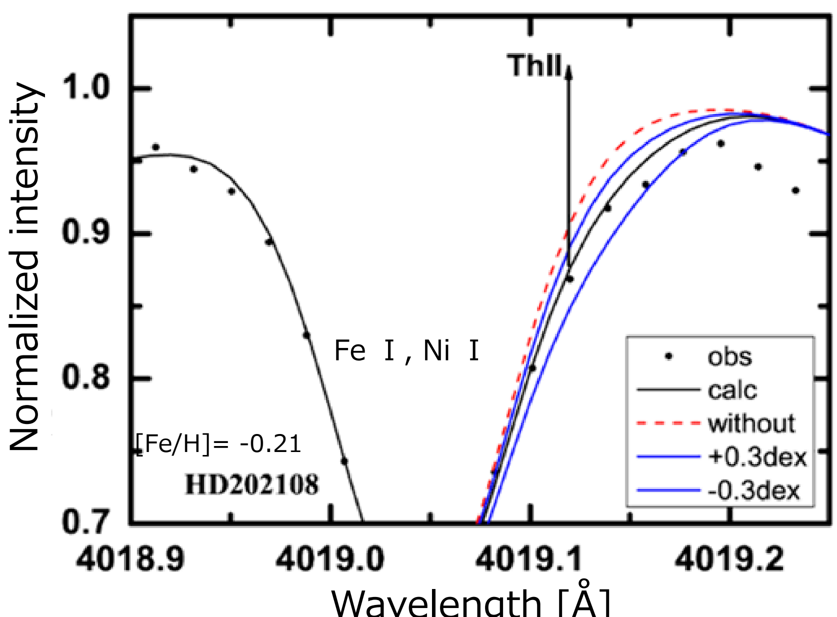
r-I:+0.3≤[Eu/Fe]≤+1.0
r-II:+1.0<[Eu/Fe]
(Beers & Christlieb 2005)

Th absorption line

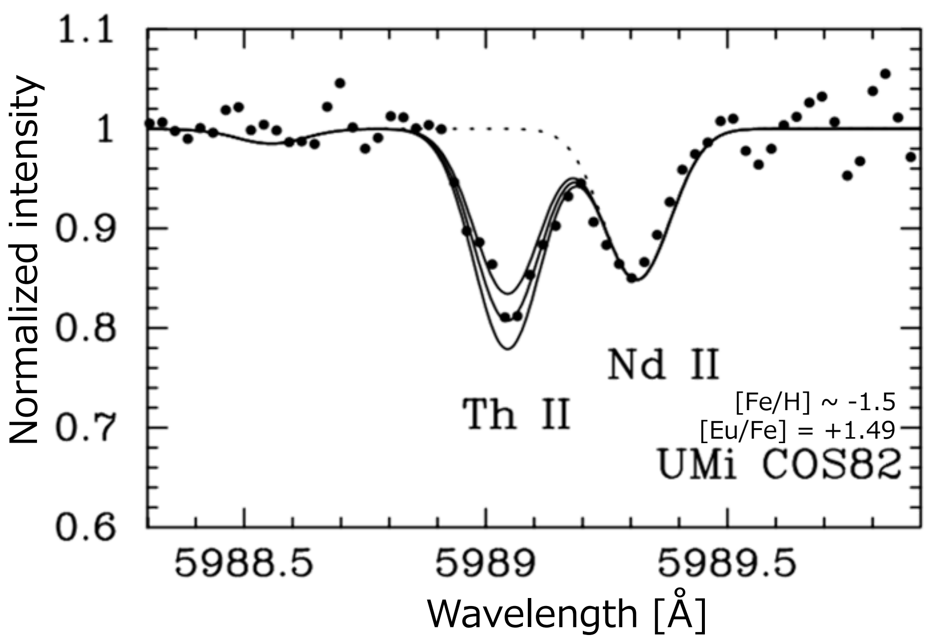
Th absorption lines are difficult to observe.

4019.1 Å
This line has **strong** intensity and has been used detecting Th.
The line observed blended with Fe, Ni, and so on. It is difficult to detect Th in **high metallicity**.

5989 Å
Although this line has weak intensity, there are few absorption line around 5989 Å.
This line may useful detecting Th in high metallicity.



(fig.2)Absorption line in 4019.1 Å (Mishenina et al., 2022).



(fig.3)Absorption line in 5989 Å (Aoki et al., 2009).

Observation

To clear the origin of r-process, we aim to detect Th in $-2 \lesssim$ [Fe/H] stars by using 5989 Å line.

(table.1) Observation information

Observatory	Nishi-Harima Astronomical Observatory
telescope	2m Nayuta telescope
Instrument	Medium And Low-dispersion Longslit Spectrograph(MALLS) echelle mode
Wavelength	4960~6800 Å
resolution	R~35000

(fig.4)Nayuta telescope and MALLS

(table.2) Stellar atmospheric parameter for object

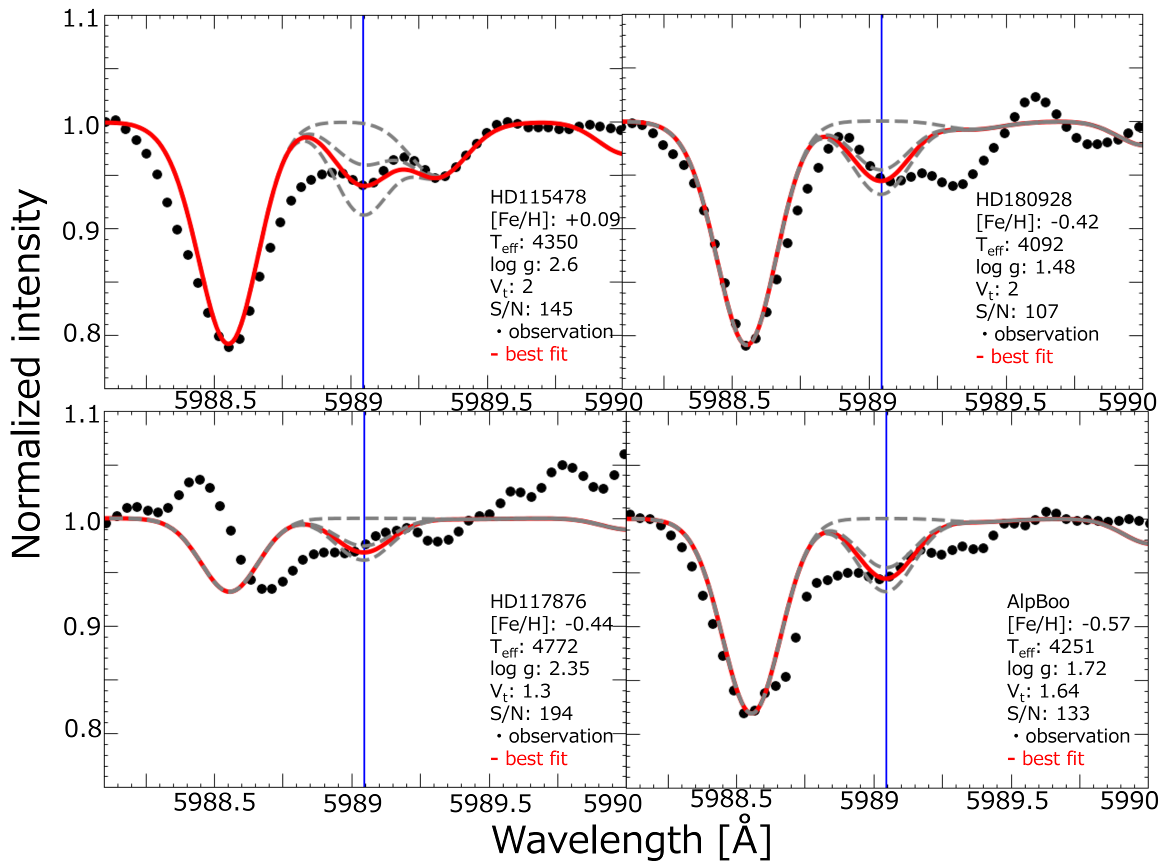
effective temperature [K]	4000 – 5000
surface gravity (log g)	1.0 – +3.8
micro turbulence [km/s]	0.7 – +1.8
[Fe/H]	-2.2 – +0.4
S/N	100 – 200

We also obtained archive data of Subaru telescope High Dispersion Spectrograph(HDS) (R~70000).

We analyzed 13 stars.

Abundance estimation

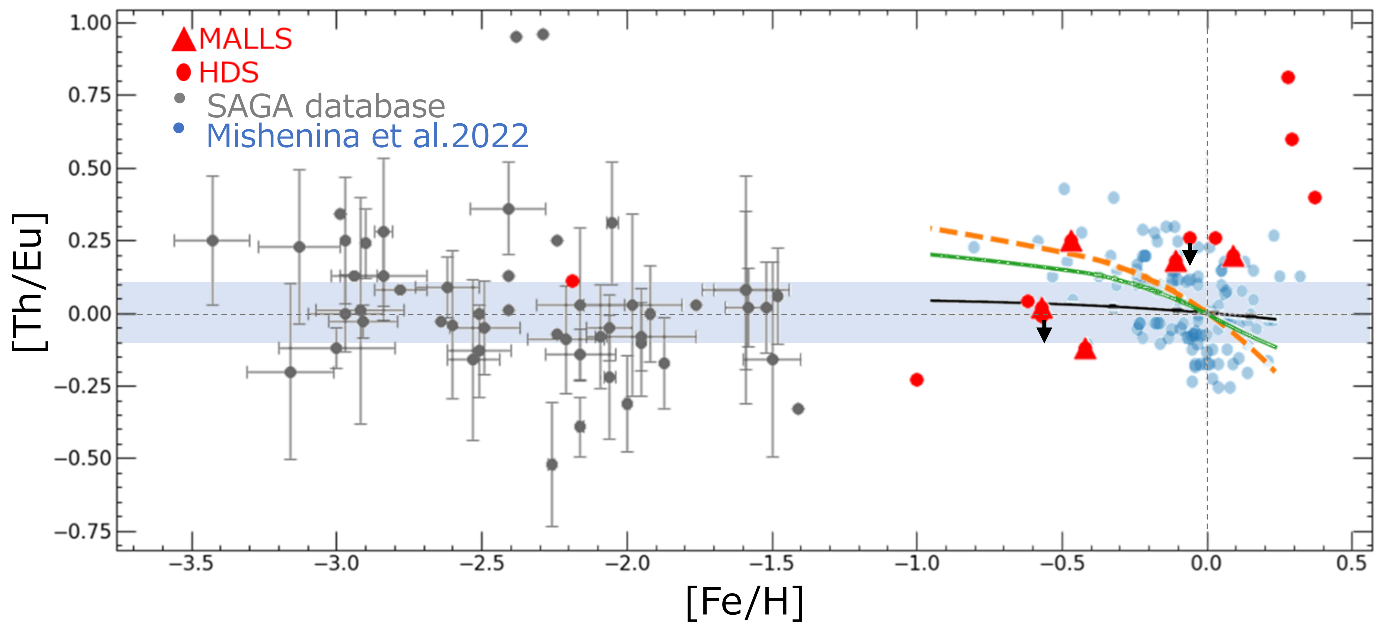
We estimated abundances by comparing the spectra obtained from observations with synthetic spectra from model atmospheres (SPTOOL Kurucz 1995, Takeda et al., 2002).



(fig.6) Spectra obtained by MALLS. Blue line is Th absorption line.

MALLS can detect Th by using 5989 Å line with <u>-0.5 ≲[Fe/H], 100 ≲ S/N, effective temperature ≲ 5000 K, surface gravity ≲ 3</u>.

Result of Th and Eu abundance estimation



(fig.7) Observed abundance of [Th/Eu] with this work.

The value of [Th/Eu] in -2 ≲ [Fe/H] ≲ 0 is no trend and independent of the metallicity, there is no actinide-boost stars in -2 ≲ [Fe/H] ≲ 0 in our sample.
The value of [Th/Eu] lager than sun by 0.5 dex in [Fe/H] > 0, 3 objects.

We need to confirm accuracy of these star abundances and increase the sample of stars in the region of [Fe/H] ~ -1.

Summery

Detect Th in −2≲[Fe/H] stars by using 5989 Å line to clear the origin of r-process.

- **MALLS can detect Th by using 5989 Å line** with -0.5 ≲[Fe/H], 100 ≲ S/N, effective temperature ≲ 5000 K, surface gravity ≲ 3.
- **We obtained Th abundance in [Fe/H] ≳ -1, 12 object**.
- There is no Actinide-boost stars in -2≲[Fe/H] in our sample.
- The value of [Th/Eu] is lager than sun by 0.5 dex in [Fe/H]>0, 3 objects.

We confirm accuracy of these star abundance and increase the sample of stars in the region of [Fe/H] ~ -1.

Please see the poster for more details.
Thank you for your attention.