

The isotopic mixture of magnesium in 47 Tucanae



Anders Overaa Thygesen
ZAH, Landessternwarte Heidelberg



The isotopic mixture of magnesium in 47 Tucanae

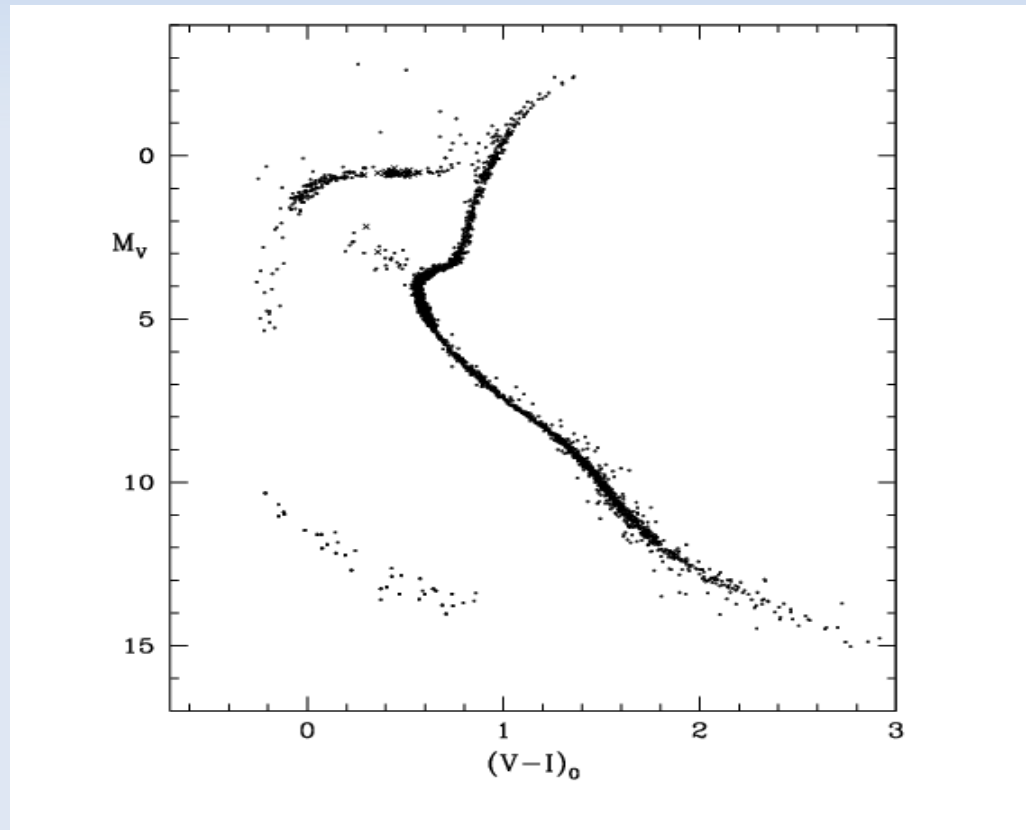
In collaboration with:

- N. Christlieb, L. Sbordone (ZAH, LSW, Heidelberg).
- D. Yong, R. Collet, M. Asplund (ANU, Mt. Stromlo).
- A. D'Ercole (INAF, Bologna).
- F. D'Antona, P. Ventura (INAF, Rome).
- J. Meléndez (IAG/USP, São Paulo).

The isotopic mixture of magnesium in 47 Tucanae

Globular clusters:

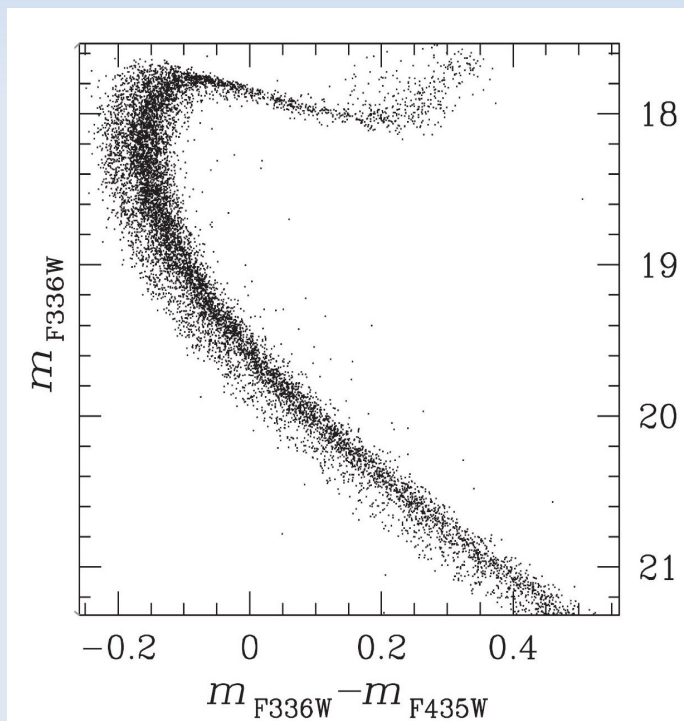
- Benchmarks for testing stellar physics.
- Earlier assumed to be simple stellar populations.



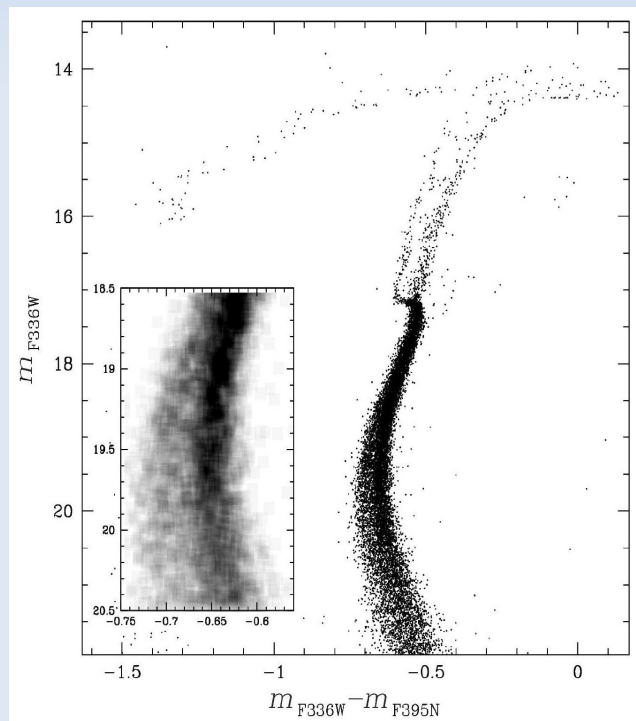
The isotopic mixture of magnesium in 47 Tucanae

Globular clusters:

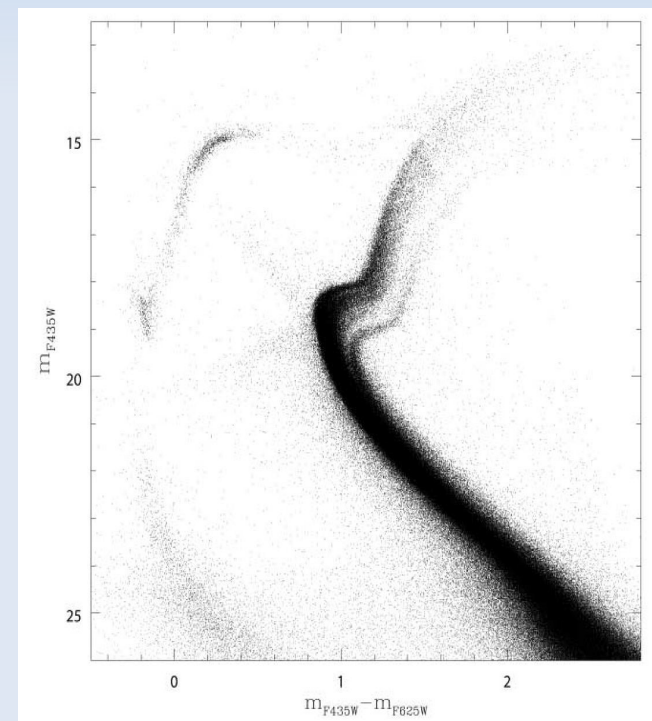
- Benchmarks for testing stellar physics.
- Contain multiple stellar populations.



(47Tuc, Milone+, ApJ 2012)



(NGC6752, Milone+, ArXiv 2013)

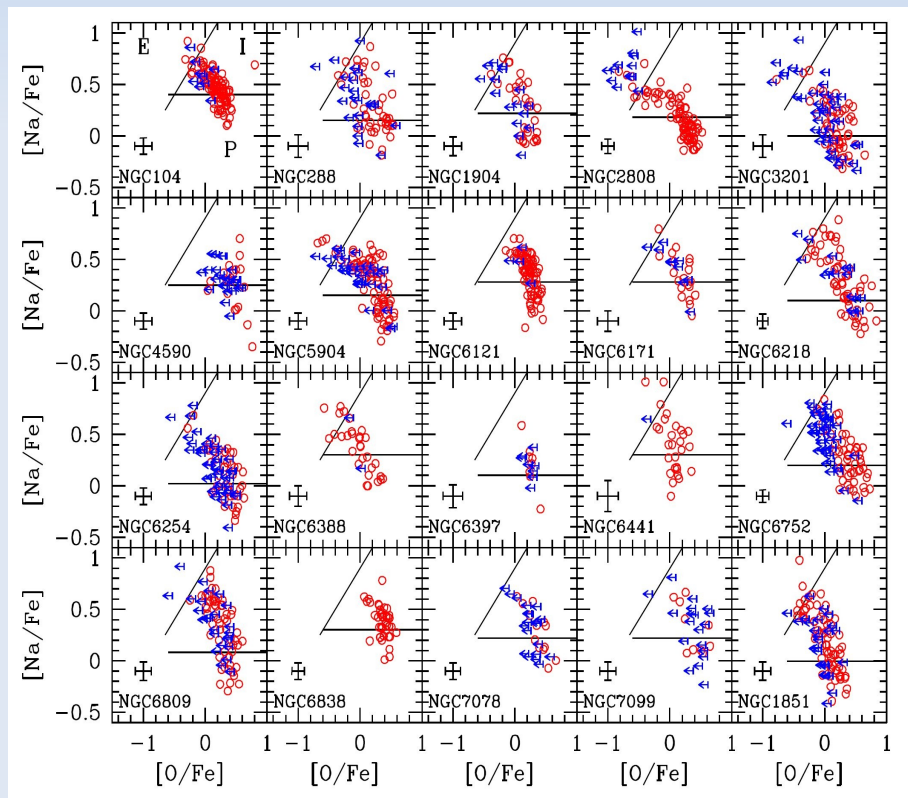


(ω Cen, Villanova+, ApJ 2007)

The isotopic mixture of magnesium in 47 Tucanae

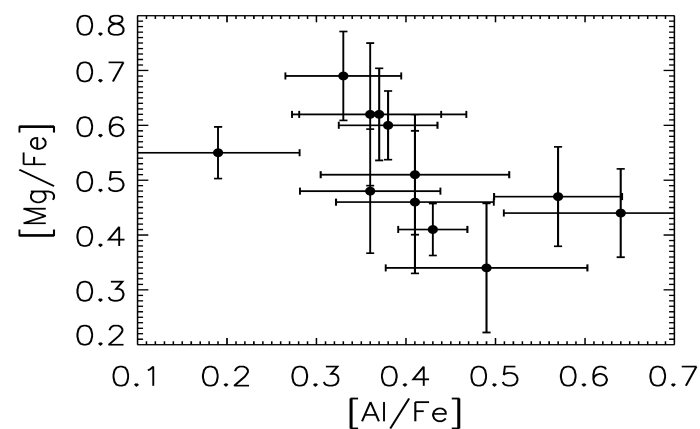
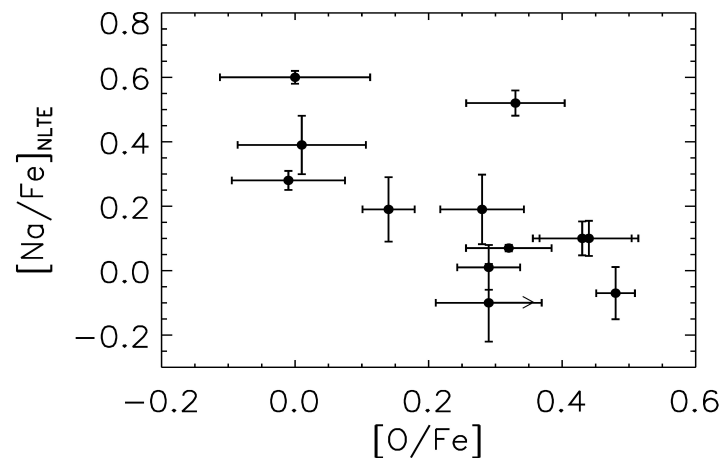
Globular clusters:

- Benchmarks for testing stellar physics.
- Contain multiple stellar populations.



(Gratton+, AAR, 2012)

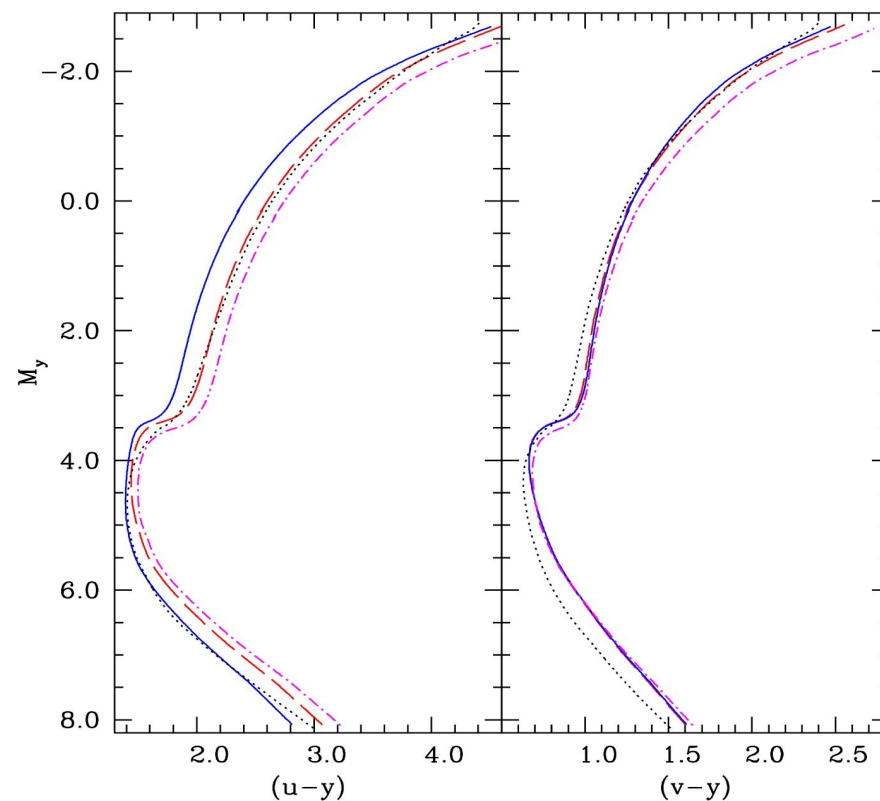
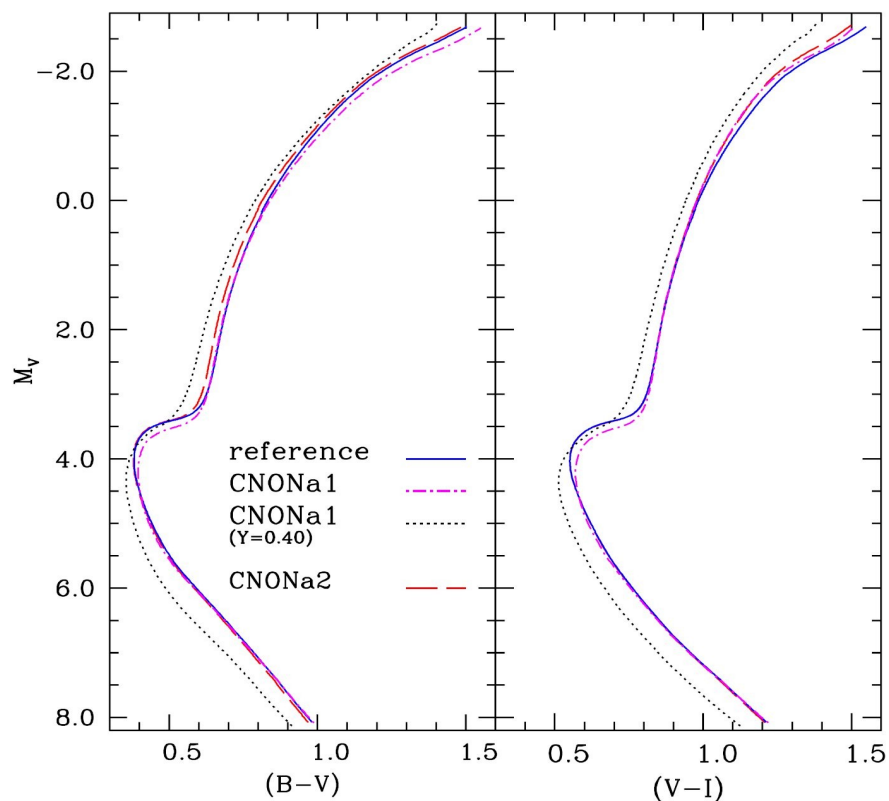
This work



The isotopic mixture of magnesium in 47 Tucanae

Globular clusters:

- Varying light element abundances.



(Sbordone+, A&A 2011)

The isotopic mixture of magnesium in 47 Tucanae

Intracluster polluters:

- AGB stars (Karakas, A., Ventura P., D'Antona, F. +....)
- Very Massive Fast Rotators (Decressin, T., Meynet, G. +)
- Massive Binaries (de Mink, S. E., Izzard, R. G. +....)

The isotopic mixture of magnesium in 47 Tucanae



$T = 0$ Myr
1st gen. stars form.

The isotopic mixture of magnesium in 47 Tucanae



$T = 0$ Myr
1st gen. stars form.



$T \sim 6$ Myr
Winds from VMFR
stars form 2nd gen.

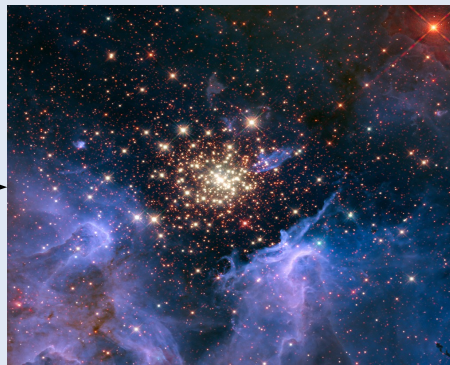
The isotopic mixture of magnesium in 47 Tucanae



$T = 0$ Myr
1st gen. stars form.

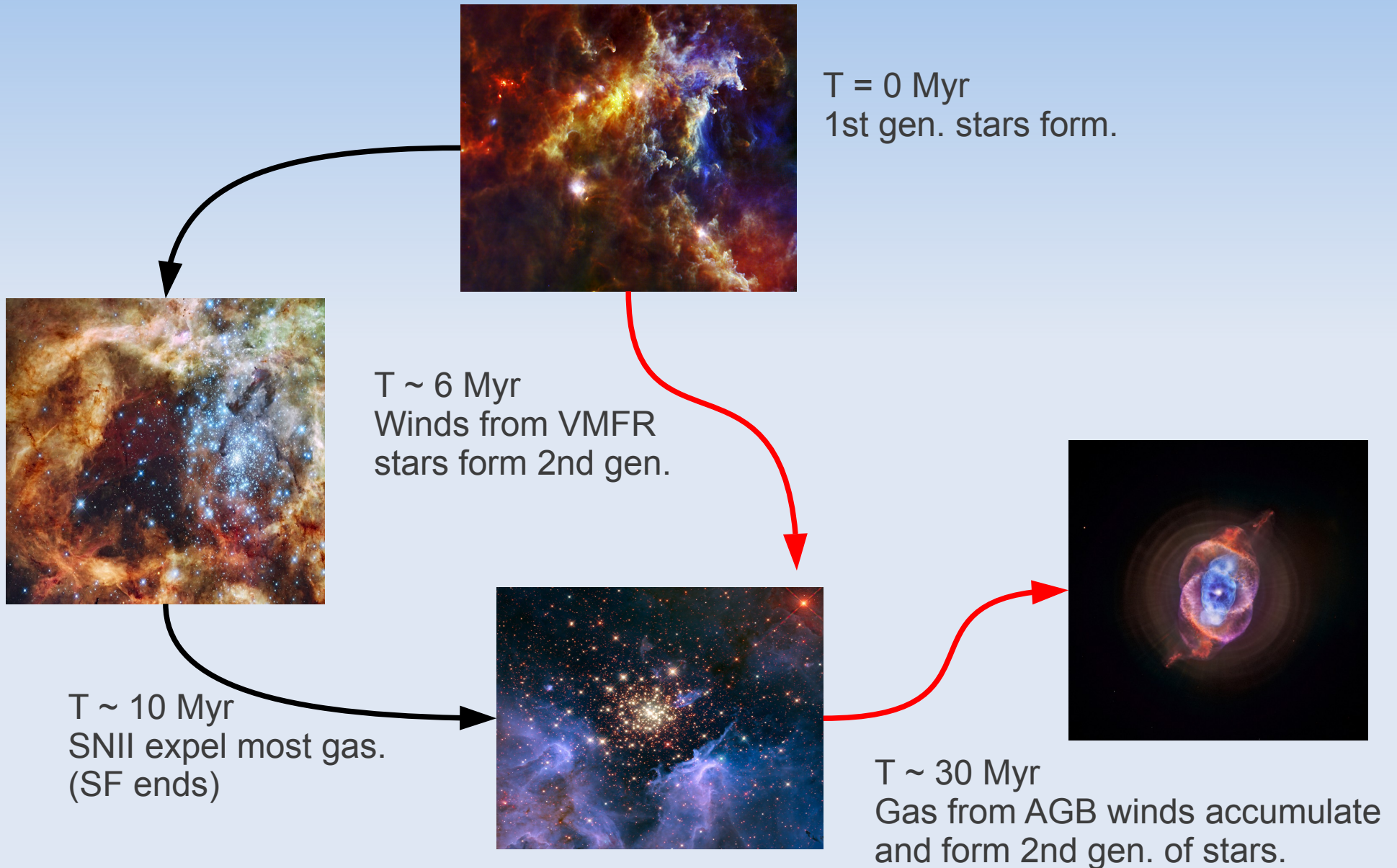


$T \sim 6$ Myr
Winds from VMFR
stars form 2nd gen.

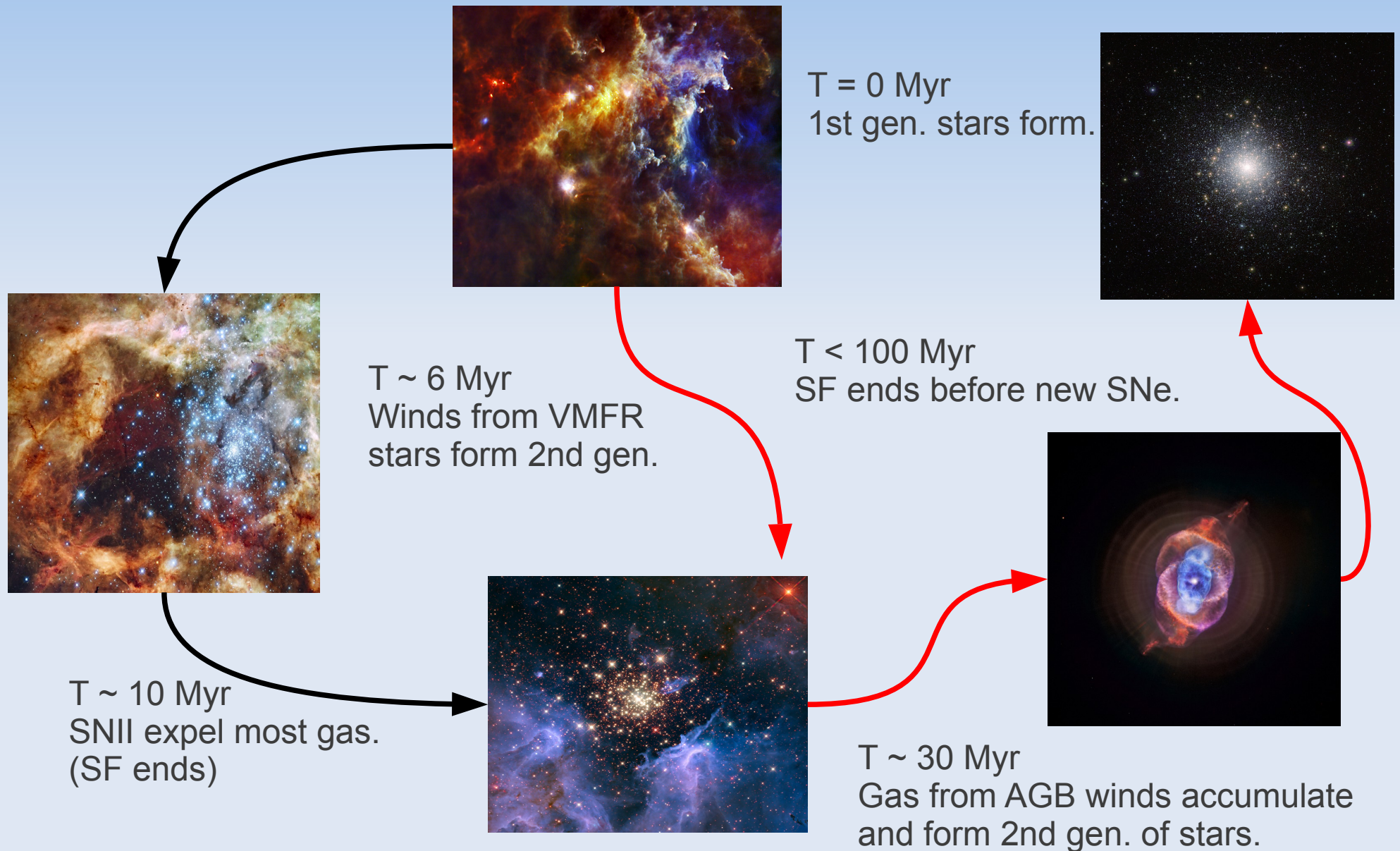


$T \sim 10$ Myr
SNII expel most gas.
(SF ends)

The isotopic mixture of magnesium in 47 Tucanae



The isotopic mixture of magnesium in 47 Tucanae



The isotopic mixture of magnesium in 47 Tucanae

Intracluster polluters:

- AGB stars (Karakas, A., Ventura P., D'Antona, F. +....)
 - Very Massive Fast Rotators (Decressin, T., Meynet, G. +)
 - Massive Binaries (de Mink, S. E., Izzard, R. G. +....)
-
- Candidate polluters can all reproduce overall picture.
 - Differences are found in the fine details

The isotopic mixture of magnesium in 47 Tucanae

Why Mg-isotopes?

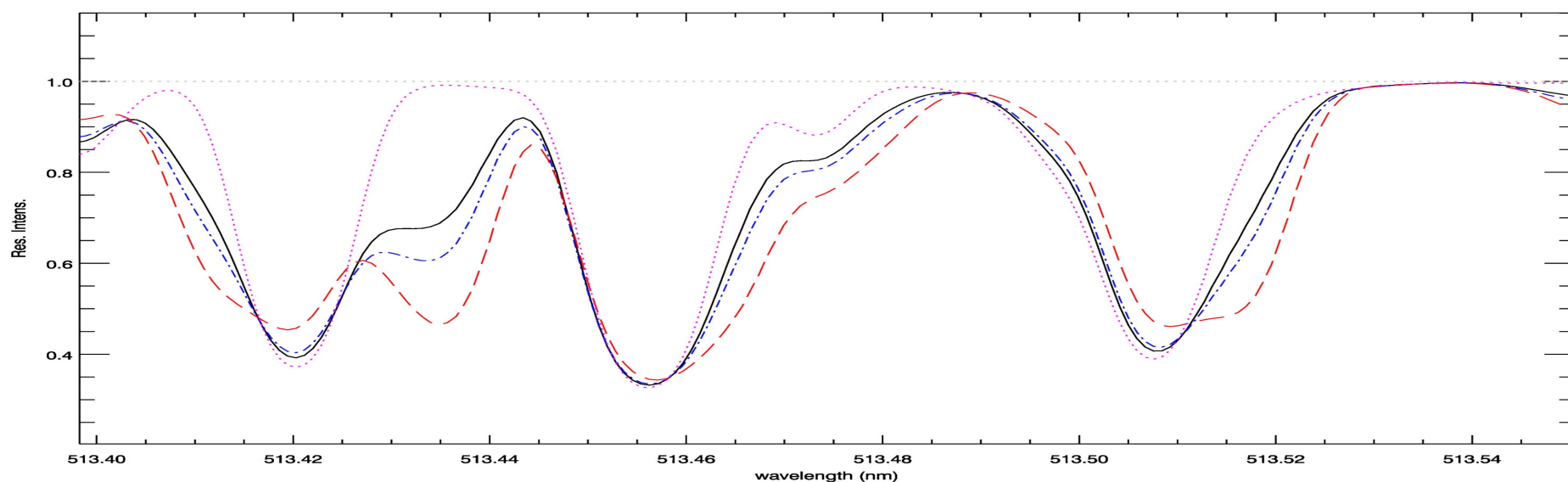
- Mg has 3 stable isotopes, ^{24}Mg , ^{25}Mg and ^{26}Mg .
- Heavy isotopes produced in non-SNe environment.
- Mg isotopes can probe differences between candidates.



The isotopic mixture of magnesium in 47 Tucanae

Why Mg-isotopes?

- Mg has 3 stable isotopes, ^{24}Mg , ^{25}Mg and ^{26}Mg
- Heavy isotopes produced in non-SNe environment.
- Mg isotopes can probe differences between candidates.
- Demanding observations ($S/N > 150$, $R \geq 90.000$)
- Can be measured only through asymmetry in MgH A-X bands.



The isotopic mixture of magnesium in 47 Tucanae

Why Mg-isotopes?

- Mg has 3 stable isotopes, ^{24}Mg , ^{25}Mg and ^{26}Mg
- Heavy isotopes produced in non-SNe environment.
- Mg isotopes can probe differences between candidates.
- Demanding observations ($S/N > 150$, $R \geq 90.000$)
- Can be measured only through asymmetry in MgH A-X bands.

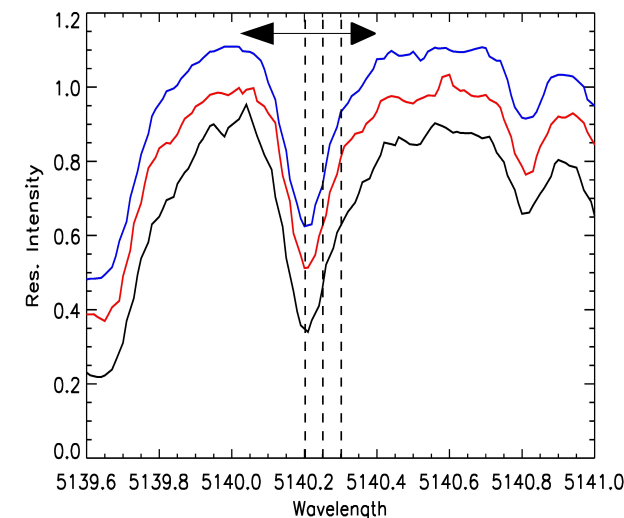
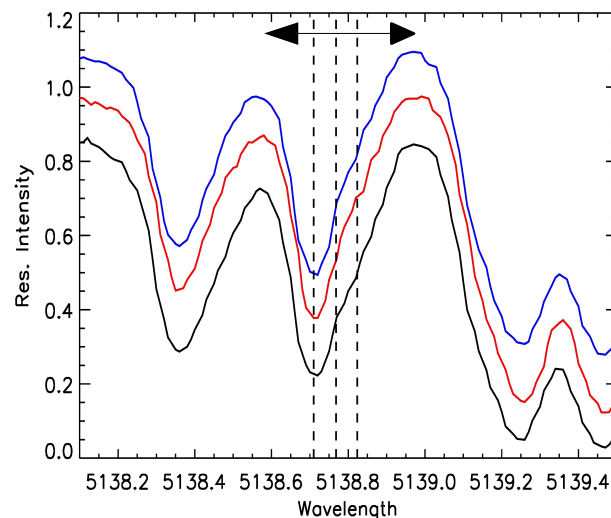
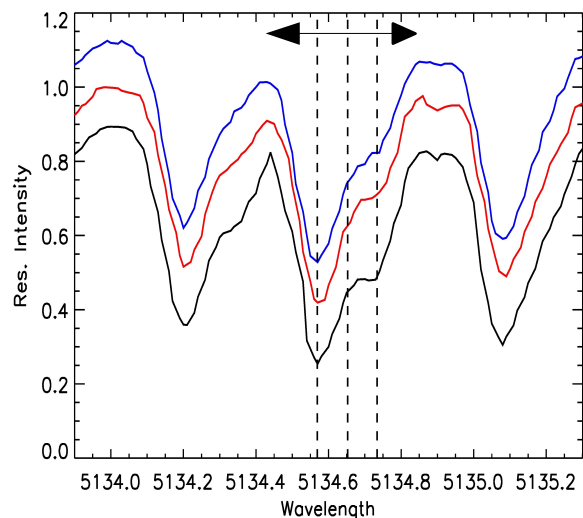
Previous work:

- M13: $[\text{Fe}/\text{H}] = -1.5$, (Shetrone, 1996, Yong+, 2005)
- NGC6752: $[\text{Fe}/\text{H}] = -1.5$, (Yong+, 2003)
- M71: $[\text{Fe}/\text{H}] = -0.8$, (Yong+, 2005, Meléndez+, 2007)
- ωCen : $[\text{Fe}/\text{H}] = [-1.8, -0.8]$ (Da Costa+, 2013)

The isotopic mixture of magnesium in 47 Tucanae

This work:

- 12 giants in 47Tuc, $[\text{Fe}/\text{H}] = -0.7$
- $T_{\text{eff}} = [3850\text{K}, 4250\text{K}]$, $\log(g) = [0.5, 1.35]$
- VLT UVES spectra ($\text{S/N} > 150$, $R = 110.000$)



The isotopic mixture of magnesium in 47 Tucanae

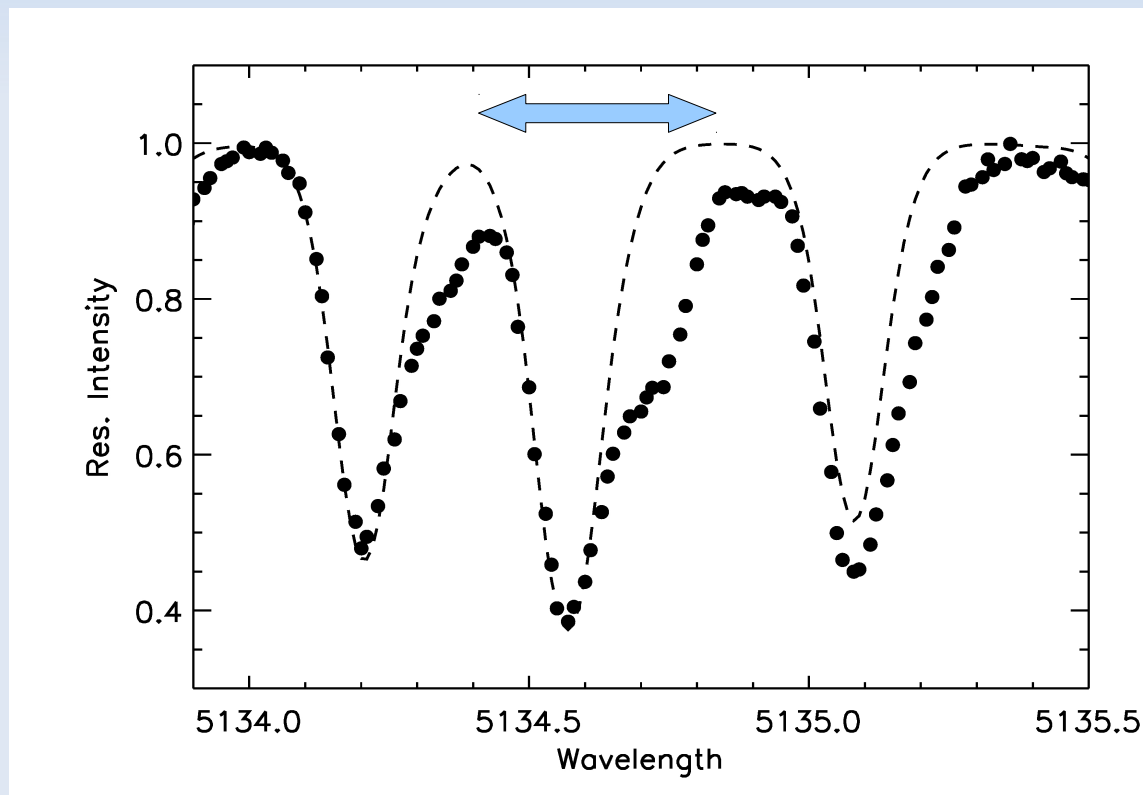
Method:

- Spectral synthesis
- MOOG + dedicated ATLAS12 1D LTE models.

The isotopic mixture of magnesium in 47 Tucanae

Method:

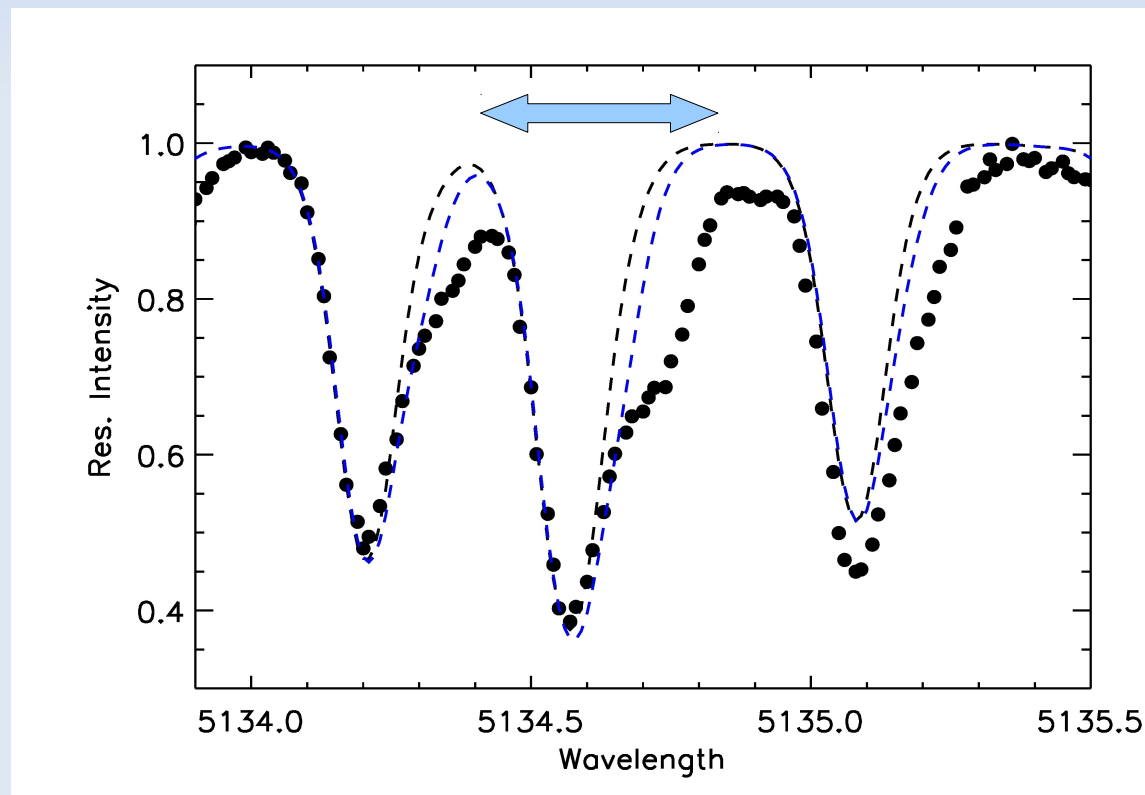
- Spectral synthesis
- MOOG + dedicated ATLAS12 1D LTE models.



The isotopic mixture of magnesium in 47 Tucanae

Method:

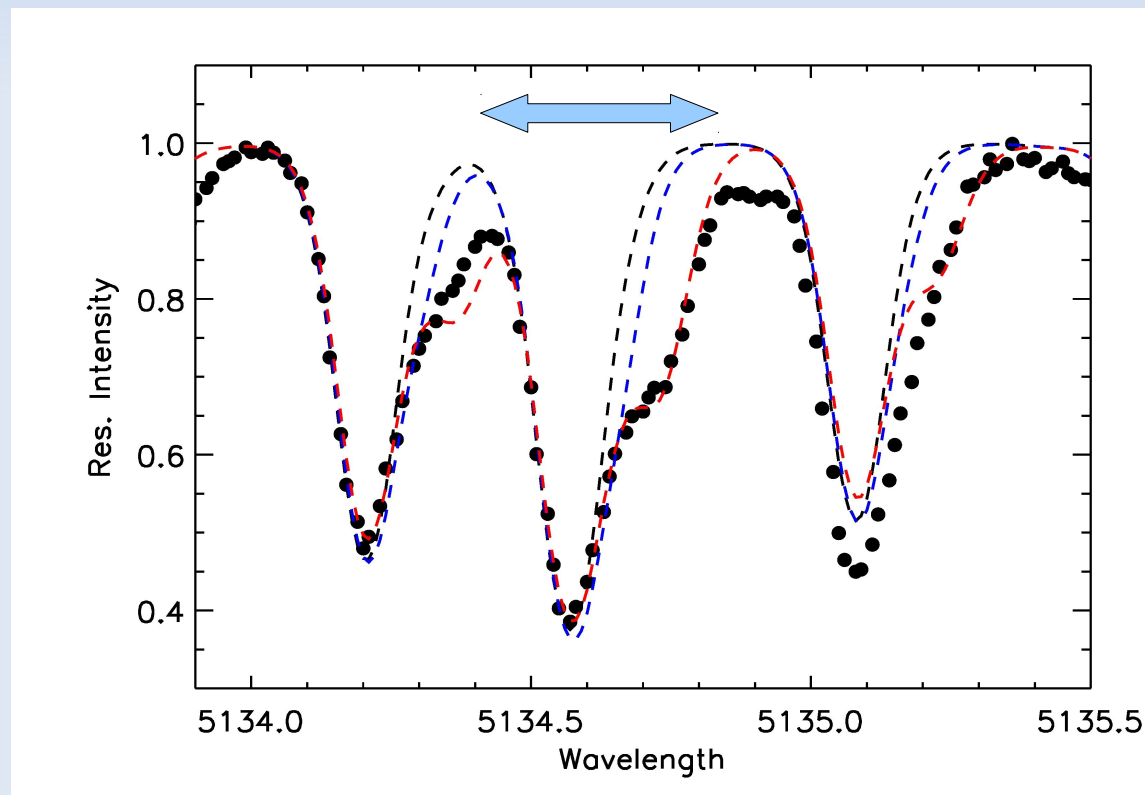
- Spectral synthesis
- MOOG + dedicated ATLAS12 1D LTE models.



The isotopic mixture of magnesium in 47 Tucanae

Method:

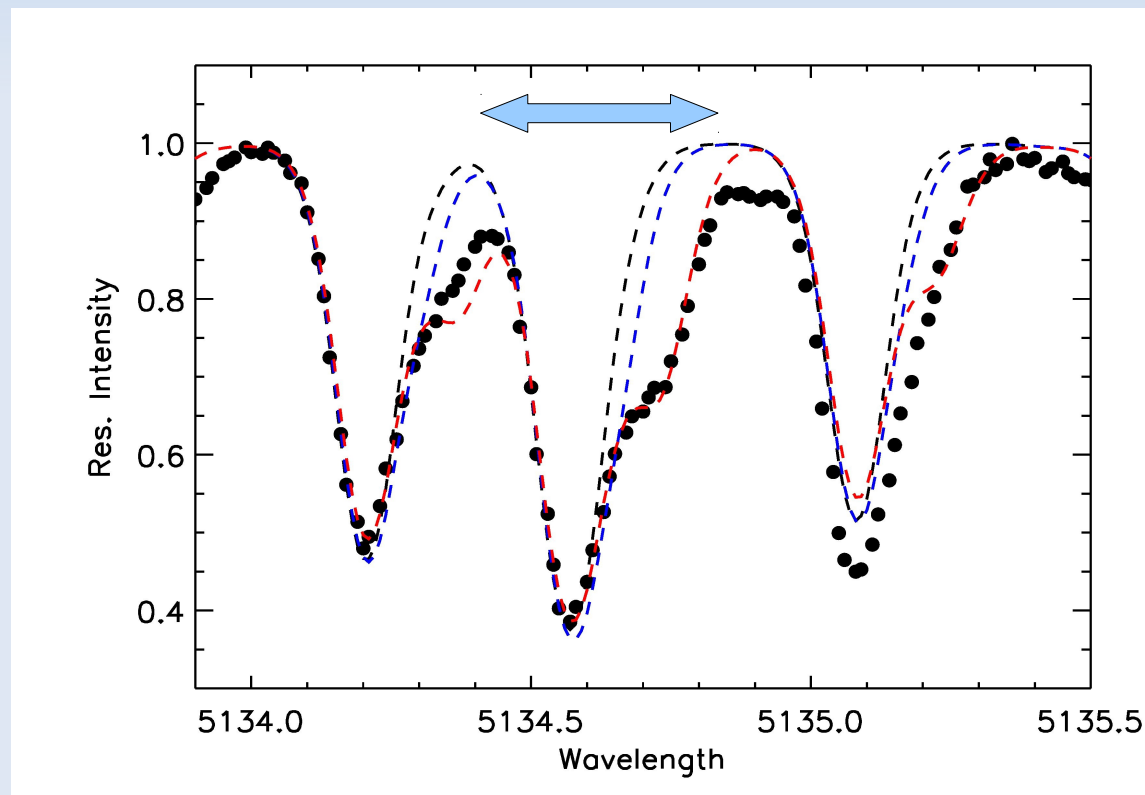
- Spectral synthesis
- MOOG + dedicated ATLAS12 1D LTE models.



The isotopic mixture of magnesium in 47 Tucanae

Method:

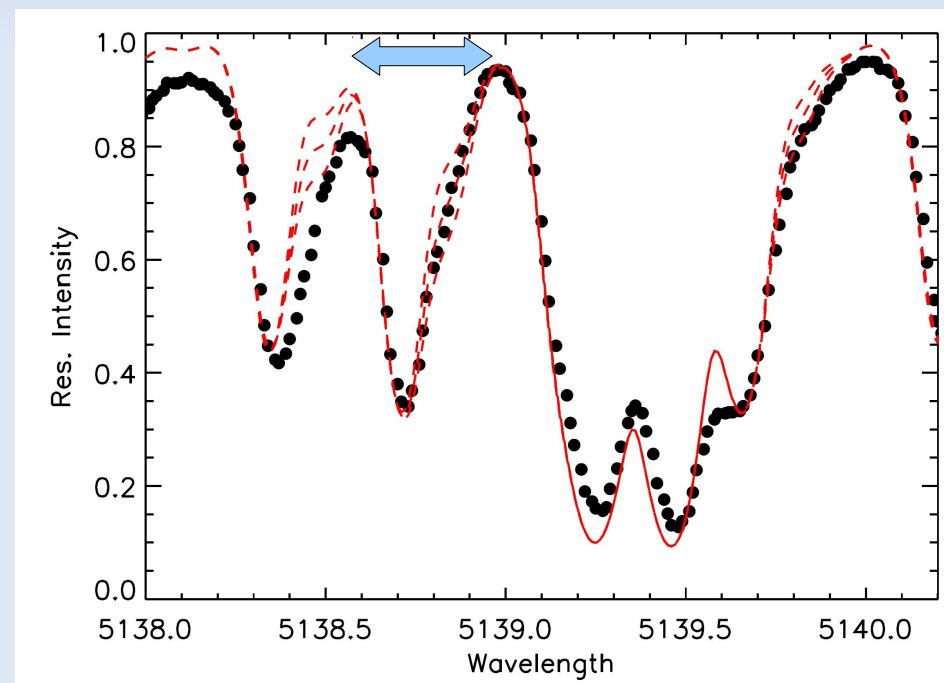
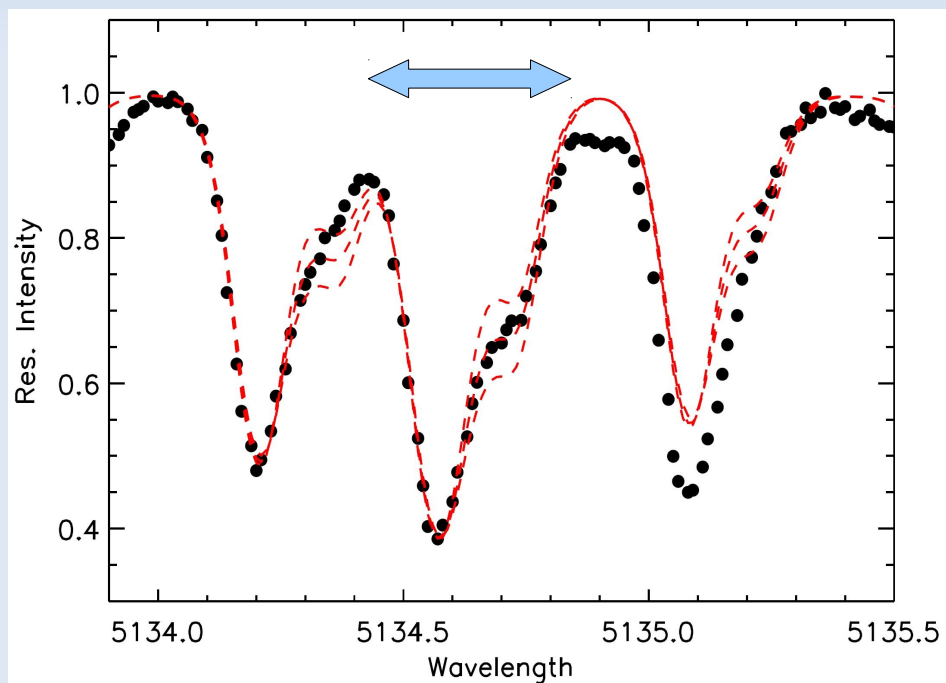
- Initial by-eye-fit of isotopic ratios.
- χ^2 -minimization using dense synthetic grid (Yong+, 2003, 2005).



The isotopic mixture of magnesium in 47 Tucanae

Results:

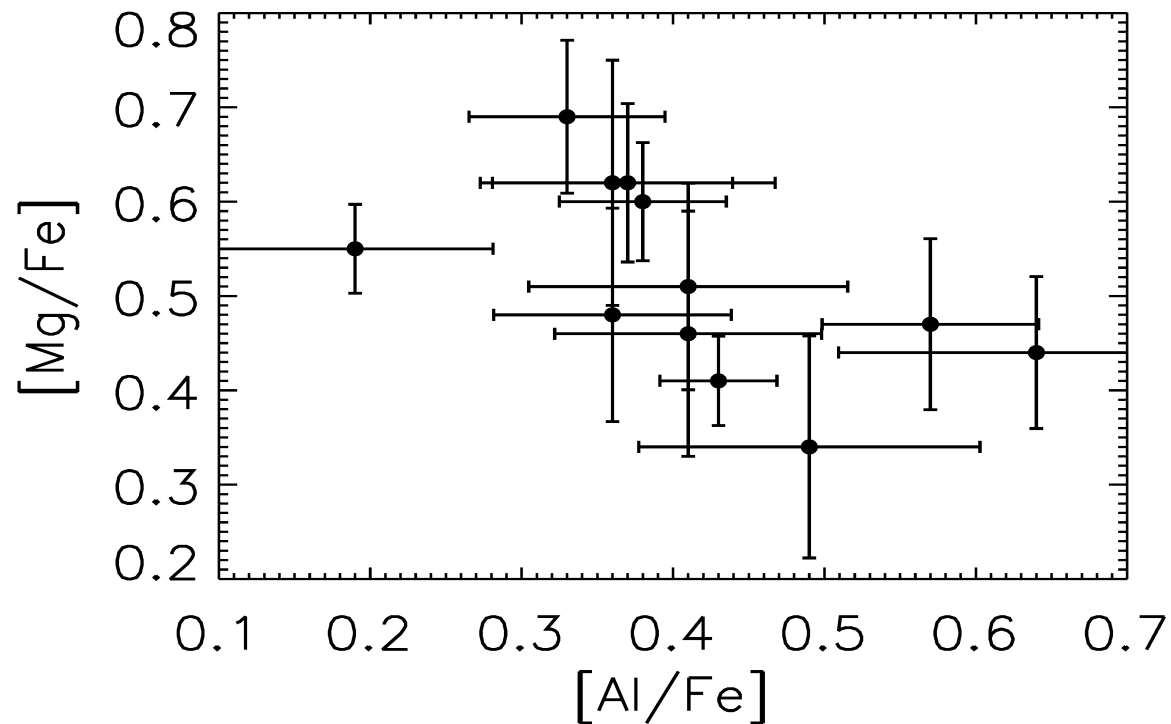
- Can determine isotopic ratios within $\pm 3\%$.
- Ratios ranging from $[^{24}\text{Mg}:^{25}\text{Mg}:^{26}\text{Mg}] = [76:13:11]$ to $[86:5:9]$



The isotopic mixture of magnesium in 47 Tucanae

Results:

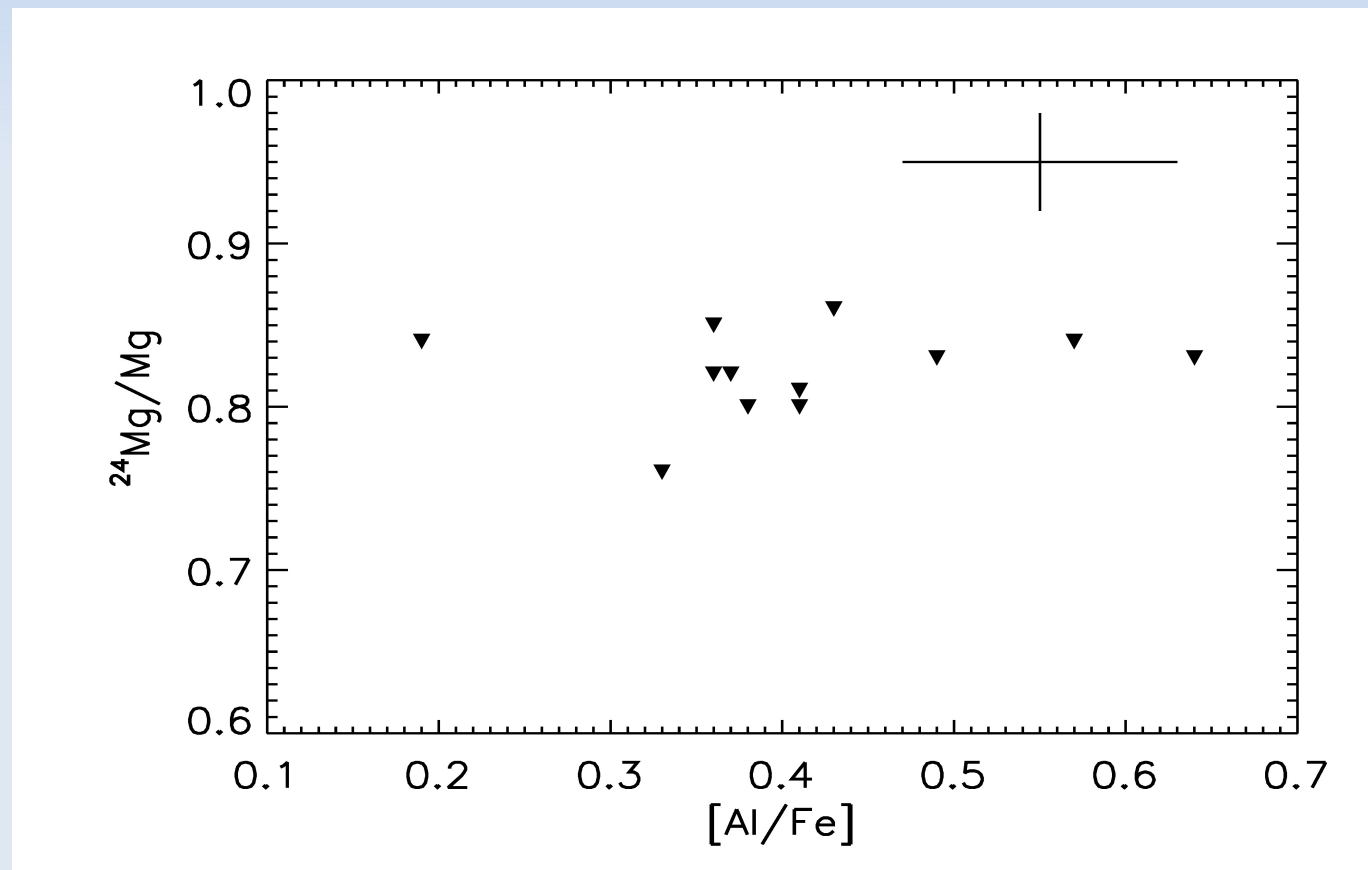
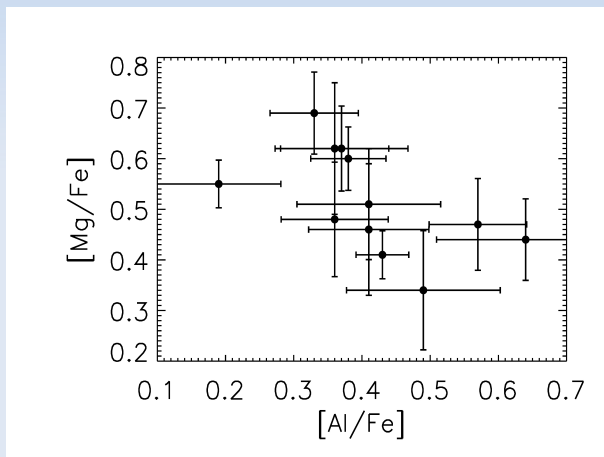
- Mg – Al anticorrelation:



The isotopic mixture of magnesium in 47 Tucanae

Results:

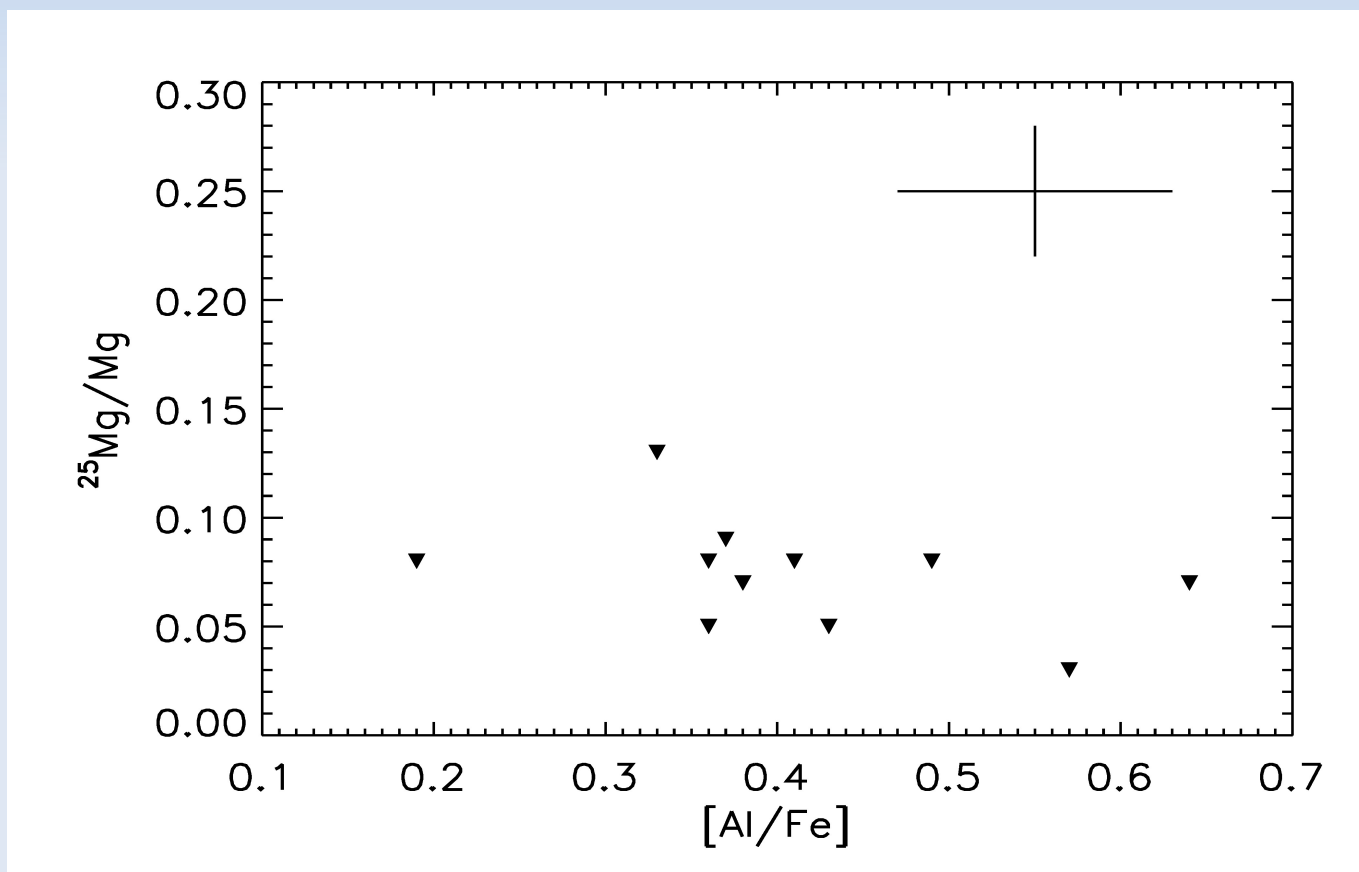
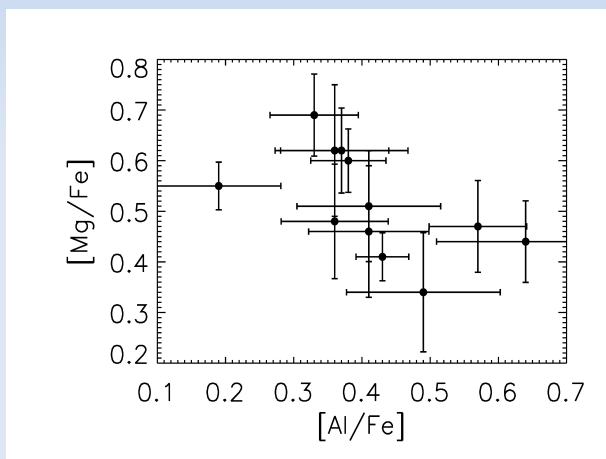
- $^{24}\text{Mg}/\text{Mg}$.



The isotopic mixture of magnesium in 47 Tucanae

Results:

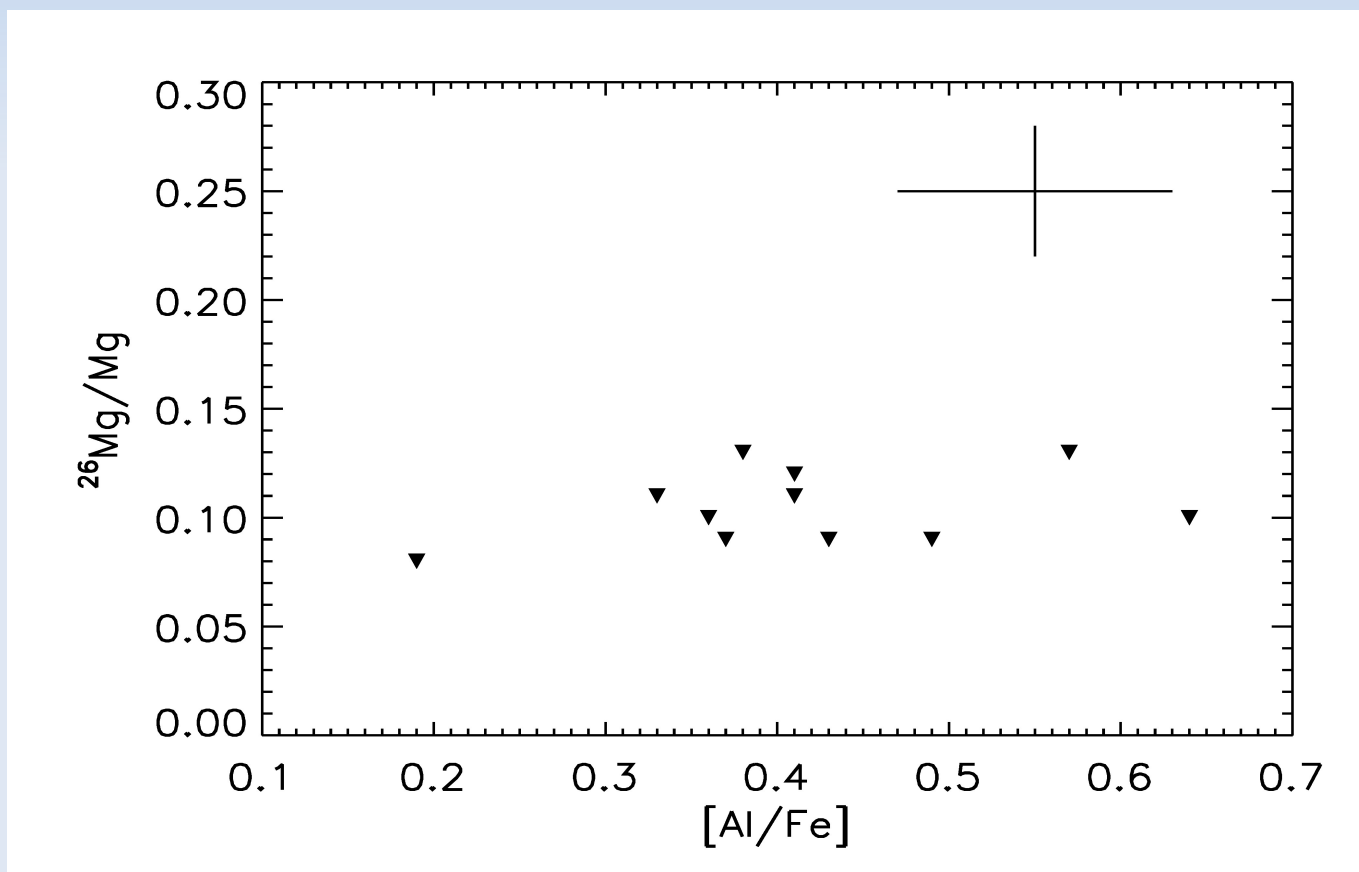
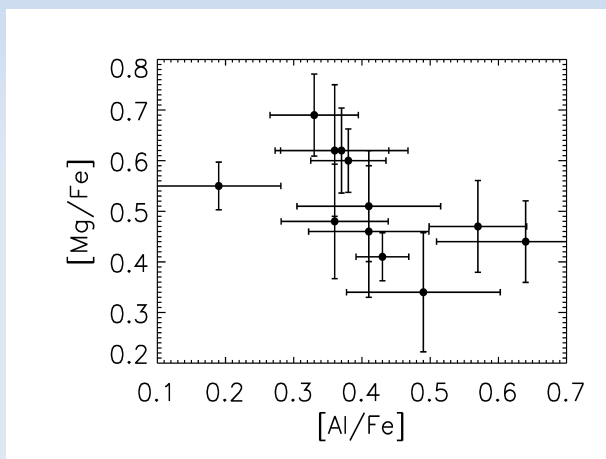
- Weak anti-correlation of $^{25}\text{Mg}/\text{Mg}$ with $[\text{Al}/\text{Fe}]$.



The isotopic mixture of magnesium in 47 Tucanae

Results:

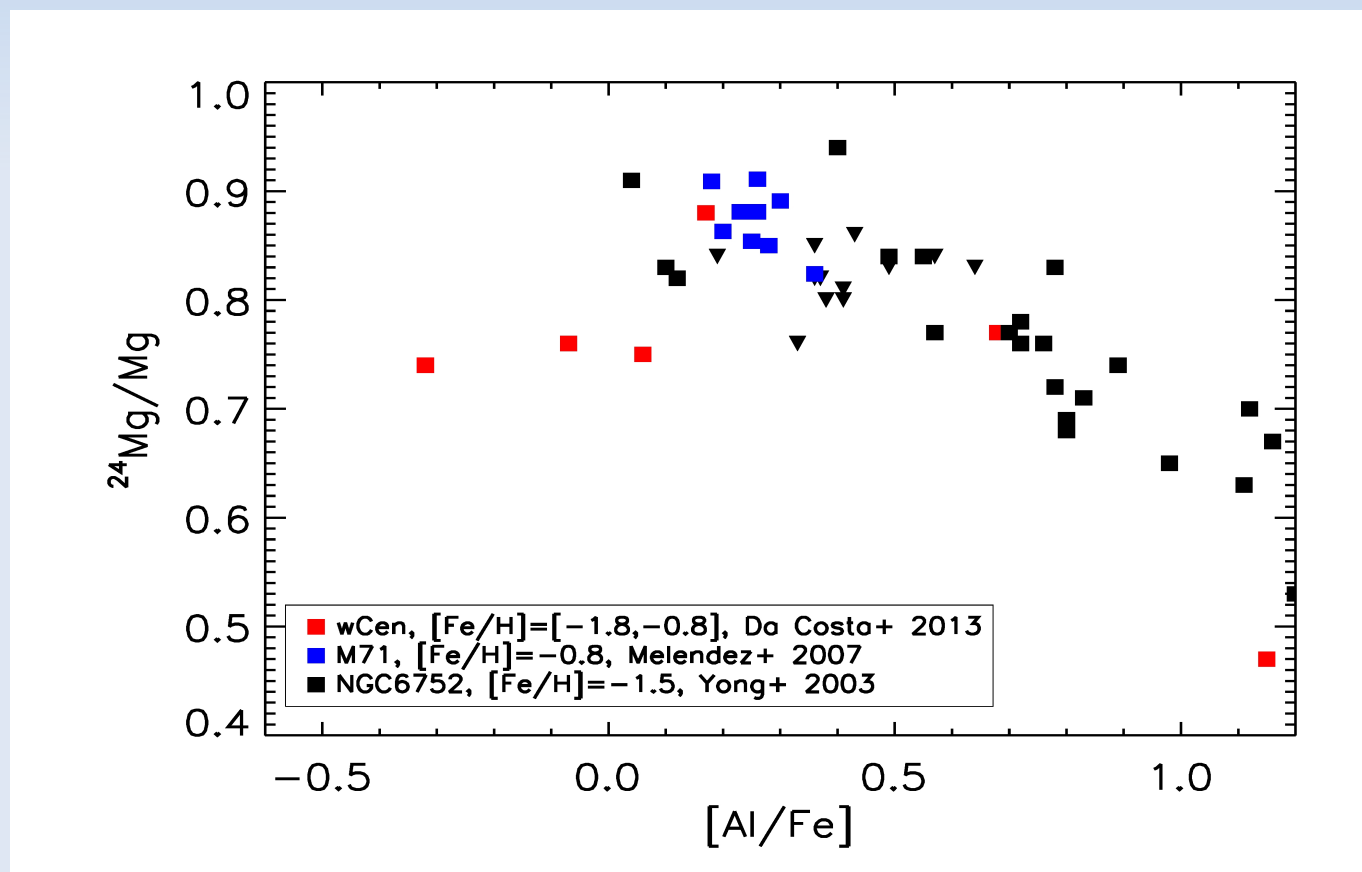
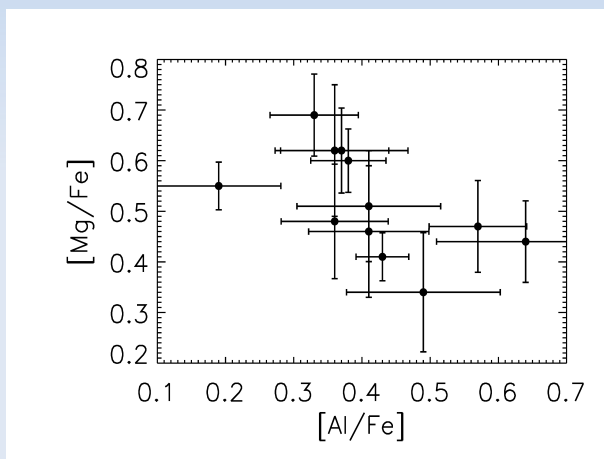
- Weak correlation of $^{26}\text{Mg}/\text{Mg}$ with $[\text{Al}/\text{Fe}]$.



The isotopic mixture of magnesium in 47 Tucanae

Comparisons:

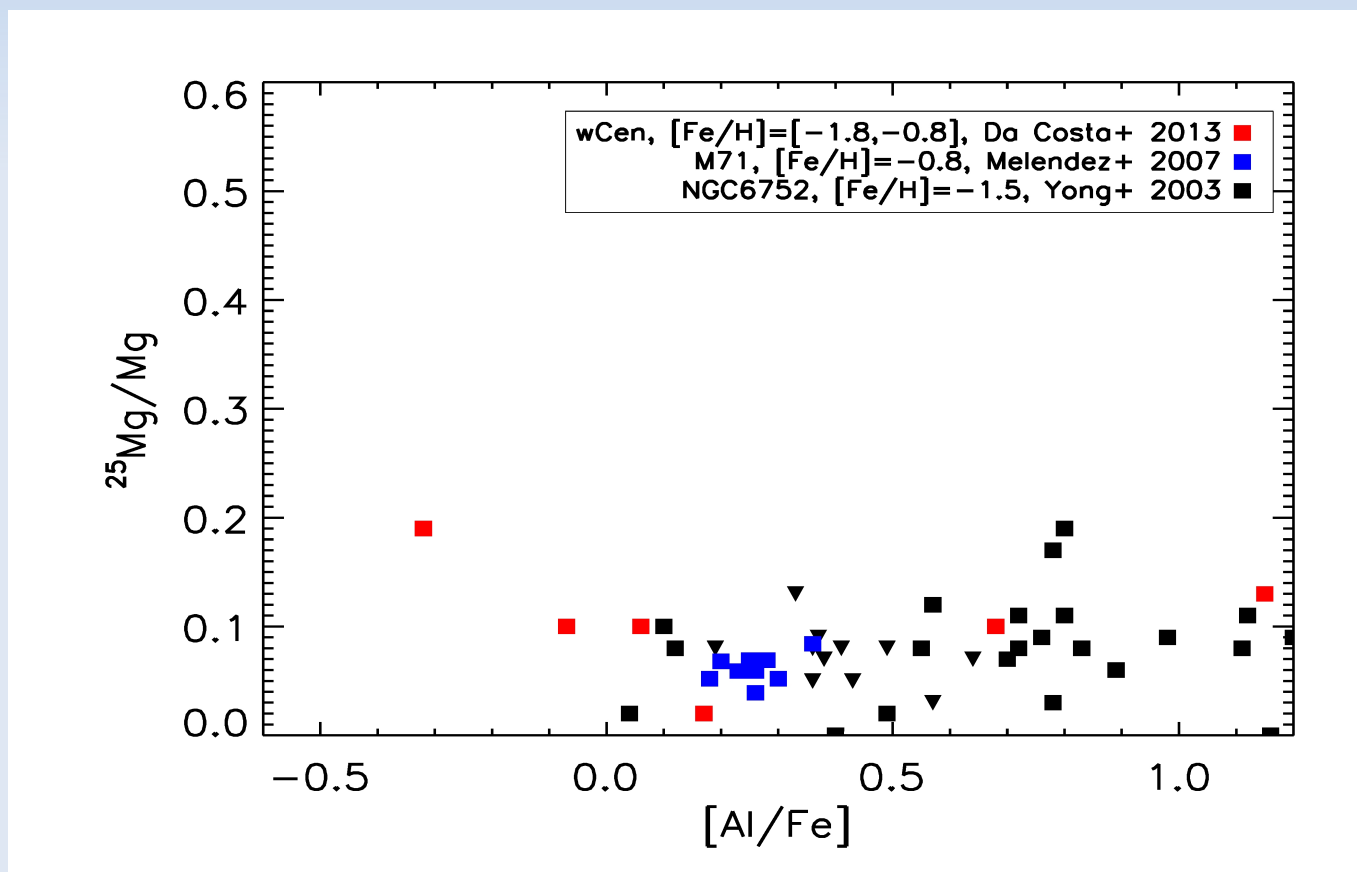
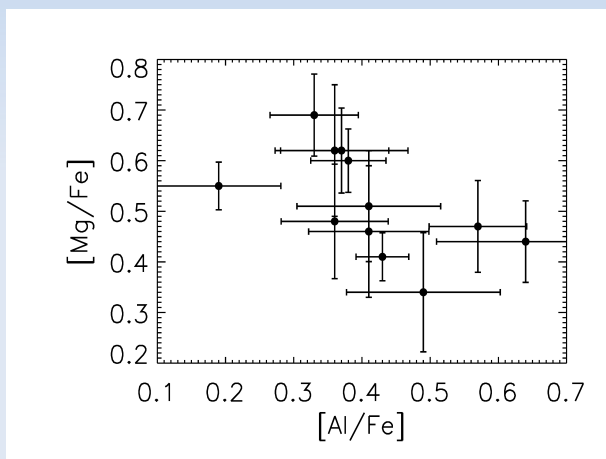
- Trend of $^{24}\text{Mg}/\text{Mg}$ with $[\text{Al}/\text{Fe}]$ observed in other clusters.



The isotopic mixture of magnesium in 47 Tucanae

Comparisons:

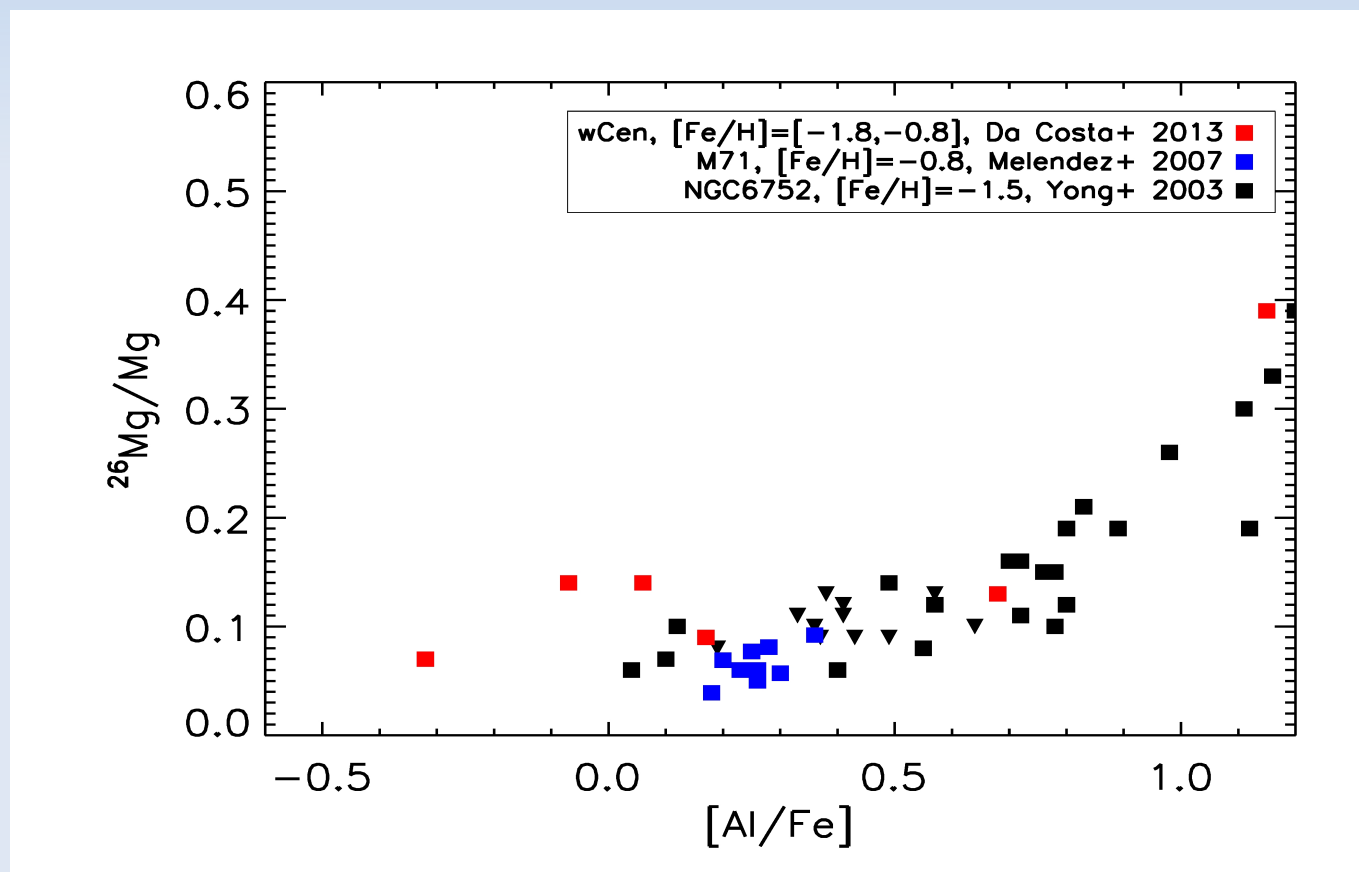
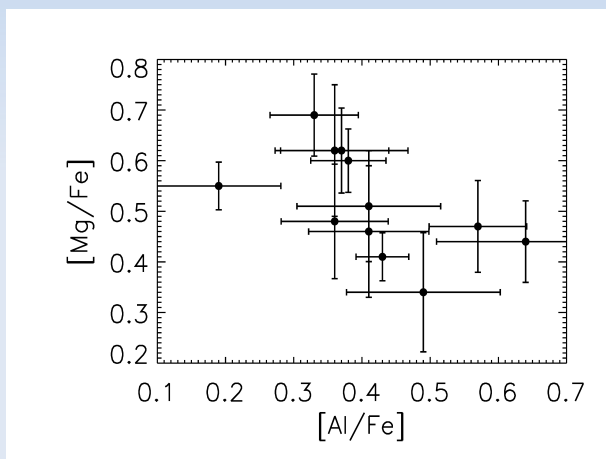
- $^{25}\text{Mg}/\text{Mg}$ is roughly constant with $[\text{Al}/\text{Fe}]$.



The isotopic mixture of magnesium in 47 Tucanae

Comparisons:

- Correlation of $^{26}\text{Mg}/\text{Mg}$ with $[\text{Al}/\text{Fe}]$.



The isotopic mixture of magnesium in 47 Tucanae

Summary:

- Mg isotopic mixture determined for highest $[\text{Fe}/\text{H}]$ cluster to date.
- Agreement with previous observations at comparable $[\text{Fe}/\text{H}]$.
- Correlations with $[\text{Al}/\text{Fe}]$ weaker in high-metallicity case.
- Provides further constraints for nature of cluster polluters.

The isotopic mixture of magnesium in 47 Tucanae

Summary:

- Mg isotopic mixture determined for highest $[\text{Fe}/\text{H}]$ cluster to date.
- Agreement with previous observations at comparable $[\text{Fe}/\text{H}]$.
- Correlations with $[\text{Al}/\text{Fe}]$ weaker in high-metallicity case.
- Provides further constraints for nature of cluster polluters.

Thank you for your attention.