Lead in intrinsically s-process enriched post-AGB stars

Kenneth De Smedt

Promotor: Hans Van Winckel

KU LEUVEN

Overview

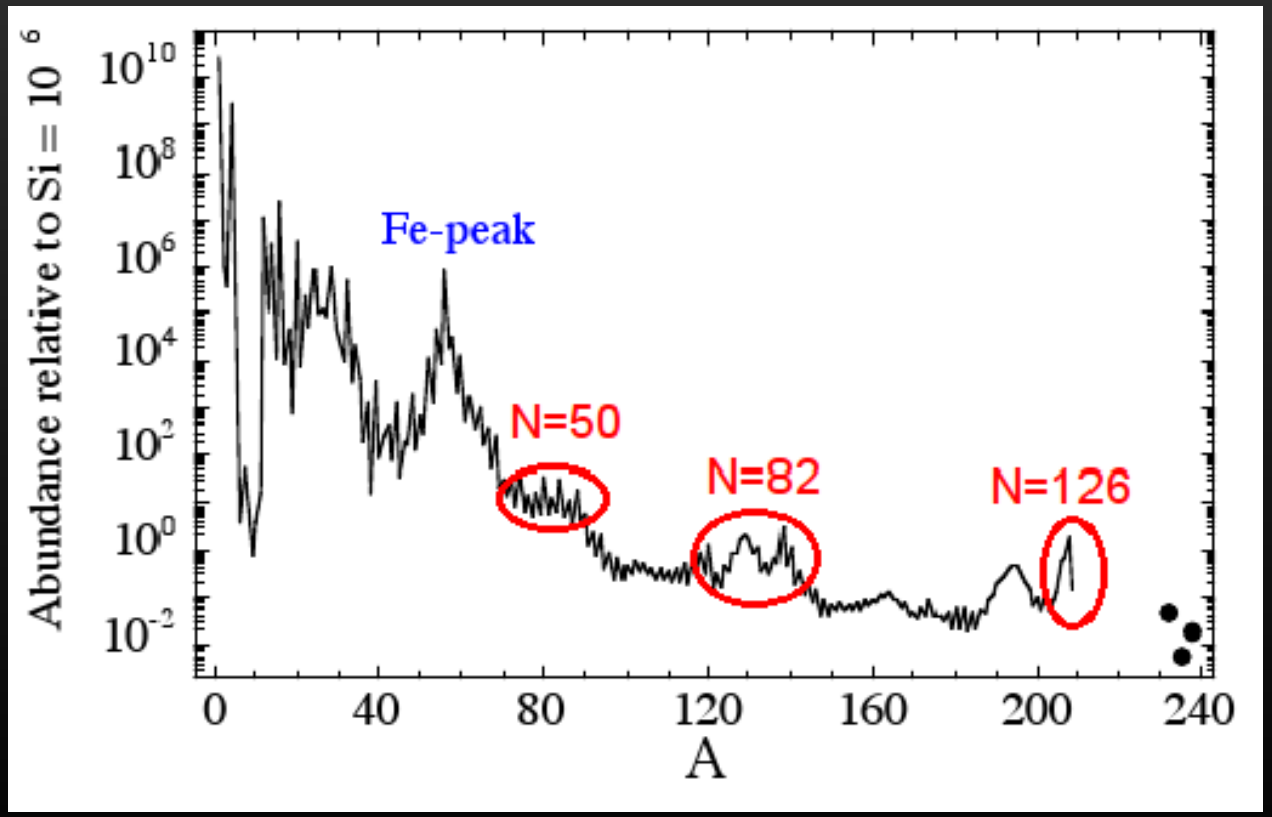
- Introduction
- An elaborate example
- Pb abundance results
- Theoretical solutions
- Conclusion

Lead

- Pb (Plumbum)
- Element 82
- Heaviest non-radioactive element

Why lead?

- End-product s-process
- Double magic neutron number



Solar abundances with s-process peaks

Why lead?

Observed Pb abundances:

Ideal test for theoretical AGB models

Based upon poorly constrained parameters:

- Mixing regimes
- Overshooting parameters
- Creation of ^{13}C-pockets
- Rotation
- …

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Expectation:

Large overabundances in metal-poor regimes

(Gallino et al, 1998 ; Lugaro et al, 2012 ; …)

Abundances: Intrinsic vs extrinsic

Intrinsic enrichment:

- Primary origin
- Single star evolution

Extrinsic enrichment:

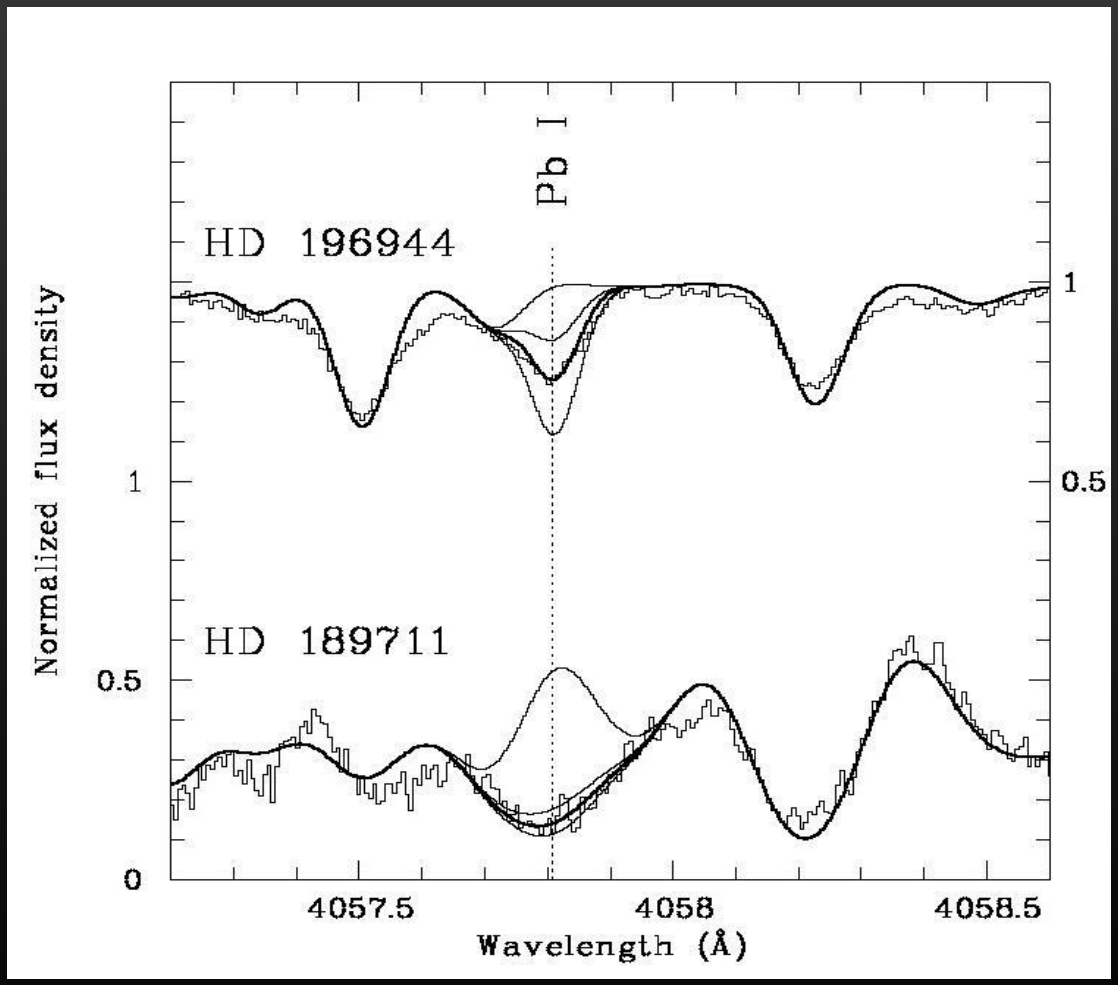
- Secondary origin
- Binary system
- Evolved companion
- Mass transfer during AGB

Extrinsic: Pb overabundance

Strong Pb overabundances in CEMP stars:

- Van Eck et al, 2001, Nature, 412, 793
- Van Eck et al, 2003, A&A, 404, 219
- Behara et al, 2010, A&A, 513, 72
- …

Extrinsic: Pb overabundance



Van Eck et al, 2003

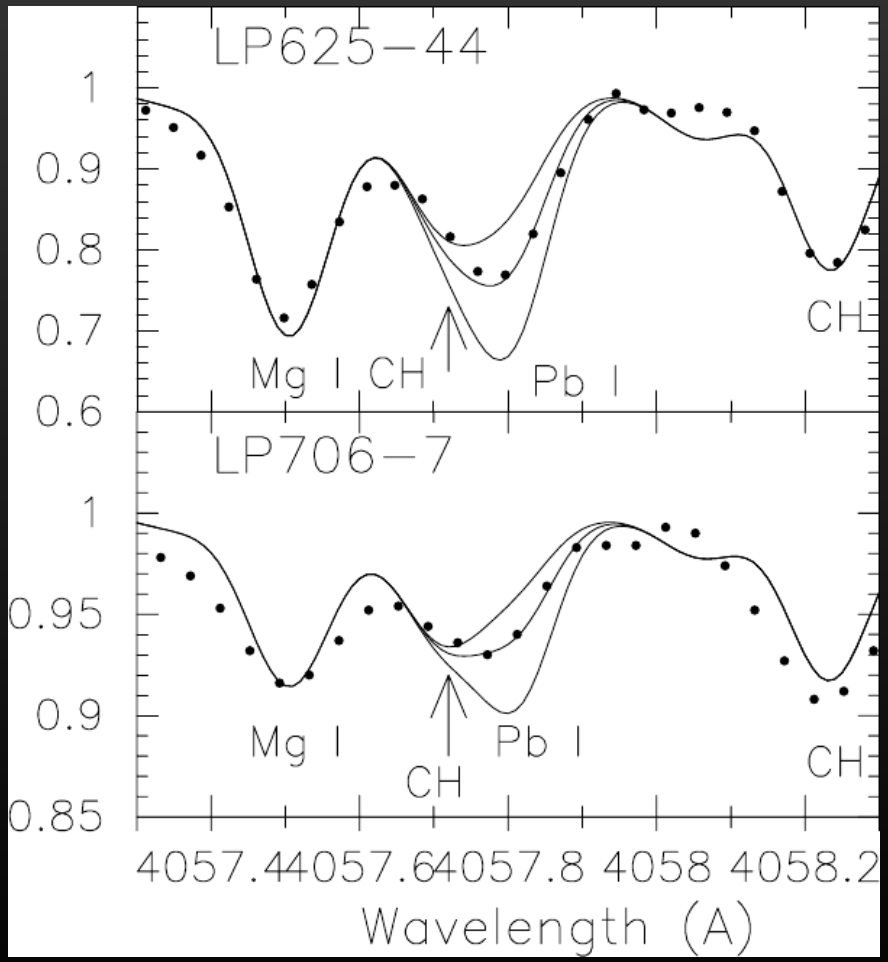
Strong Pb line detection at 4057.807 Å

… and no Pb overabundance

But not in all CEMP stars:

- Aoki et al, 2001, ApJ, 561, 346
- Van Eck et al, 2003, A&A, 404, 219
- …

… and no Pb overabundance



Aoki et al, 2001

No clear Pb line detection at 4057.807 Å

Intrinsic sample

Before 2014

Only one Pb abundance study of intrinsically s-process enriched star:

MACHO 47.2496.8

- Post-AGB star
- LMC object
- Metal-poor: [Fe/H] = -1.42

Intrinsic Pb abundance

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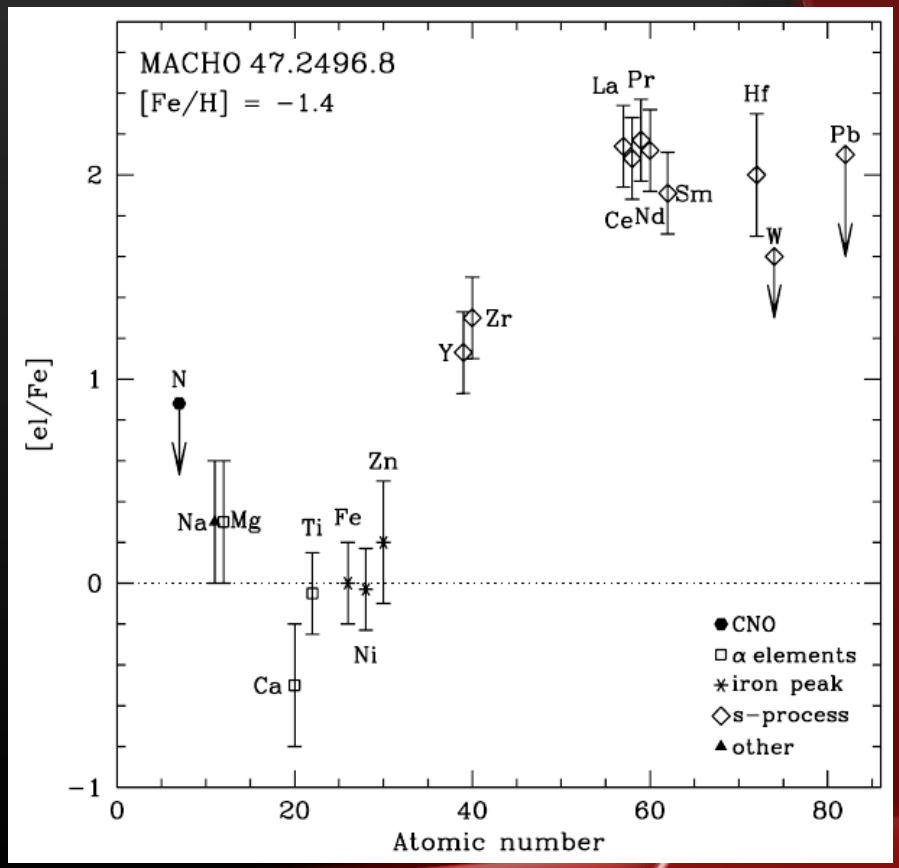
No detected Pb overabundance



Reyniers et al, 2007

Post-AGB stars

- Photosphere dominated by atomic transitions
  - CNO
  - S-process up to Pb
- No more large amplitude pulsations
- Reflects entire AGB nucleosynthesis

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But unfortunately very rare …

- Lifetime (100 – 10000 years)
- ± 1 for each 100 AGB stars

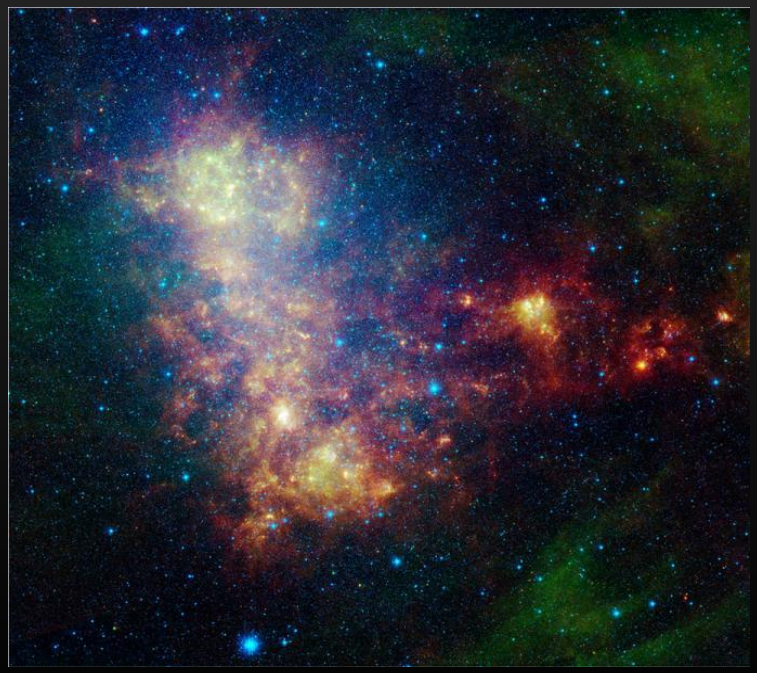
Magellanic Clouds

Why extra-galactic?

- Constrained distance to star: luminosity → initial mass
- Range in metallicity

Surveys

- LMC - van Aarle et al., 2011, Kamath et al, in prep; SMC - Kamath et al., 2014

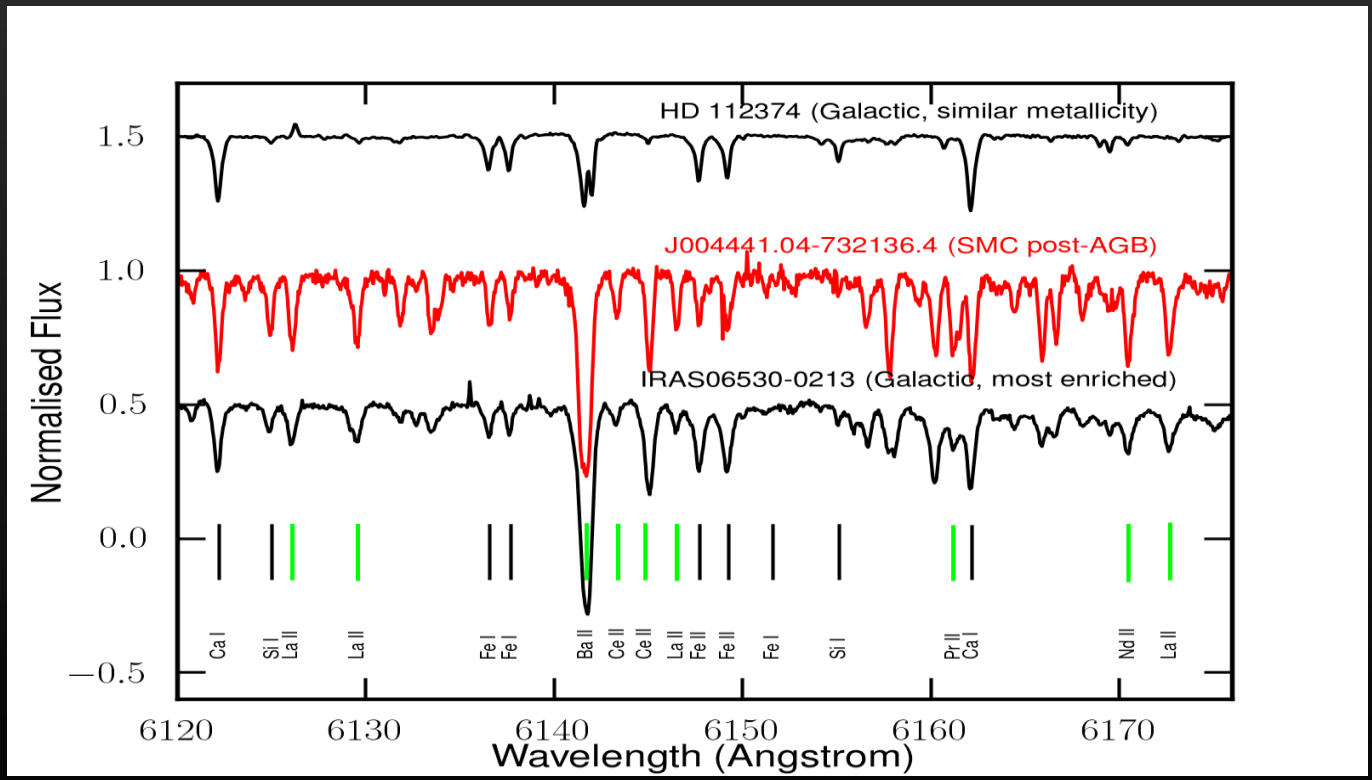


Spitzer image SMC

Spitzer image LMC

Post-AGB spectra

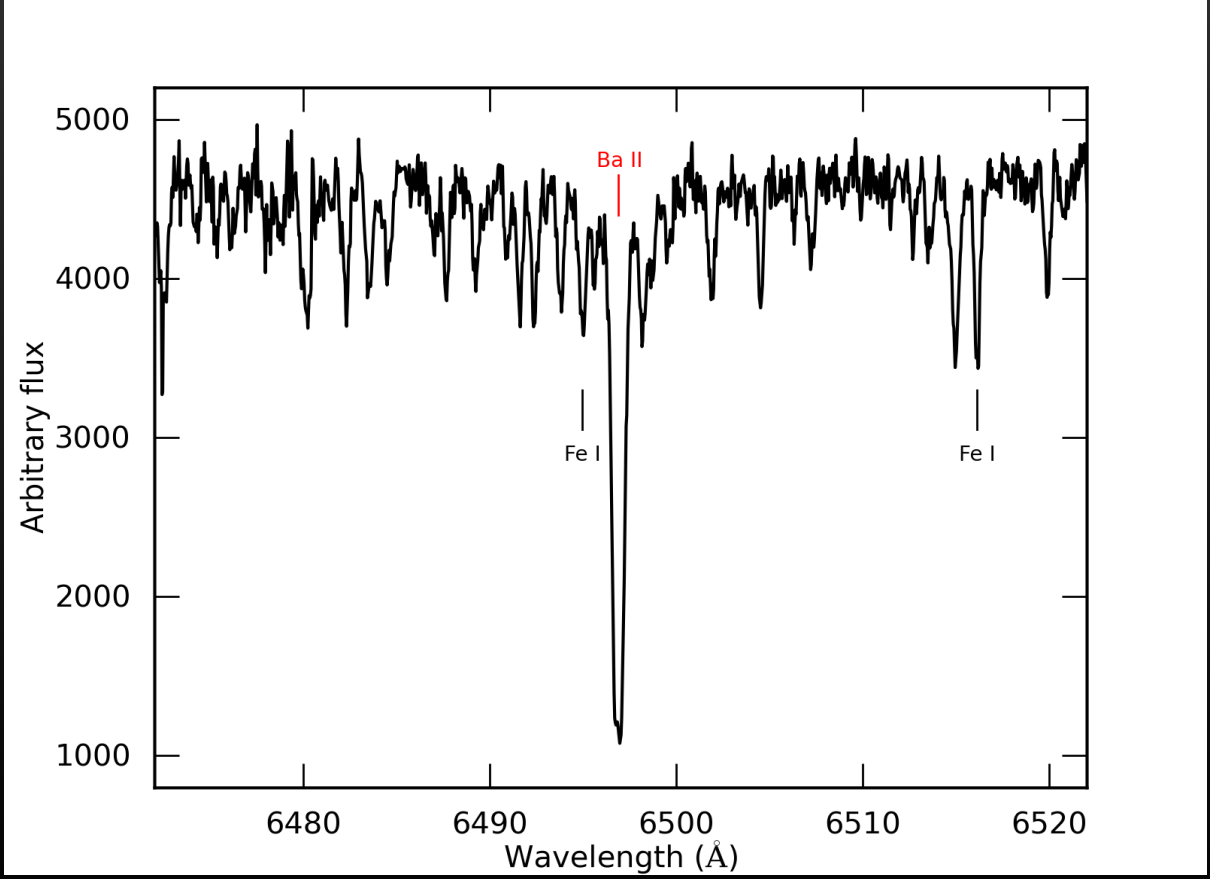
- Enriched vs non-enriched
- Atmospheric parameters
- Abundance determination



Spectra of 3 post-AGB stars

Elaborate example

- SMC post-AGB J004441.04-732136.4



De Smedt et al, 2012

Spectrum of J004441.04 at Ba II line at 6496.897 Å

Analysis

- EW calculation
- Kurucz-Castelli atmospherical models

  (Castelli & Kurucz, 2004)
- VALD linelists (NIST)
- LTE- abundance analysis code MOOG

  (Sneden, 1973)

Analysis: Atmospheric parameters

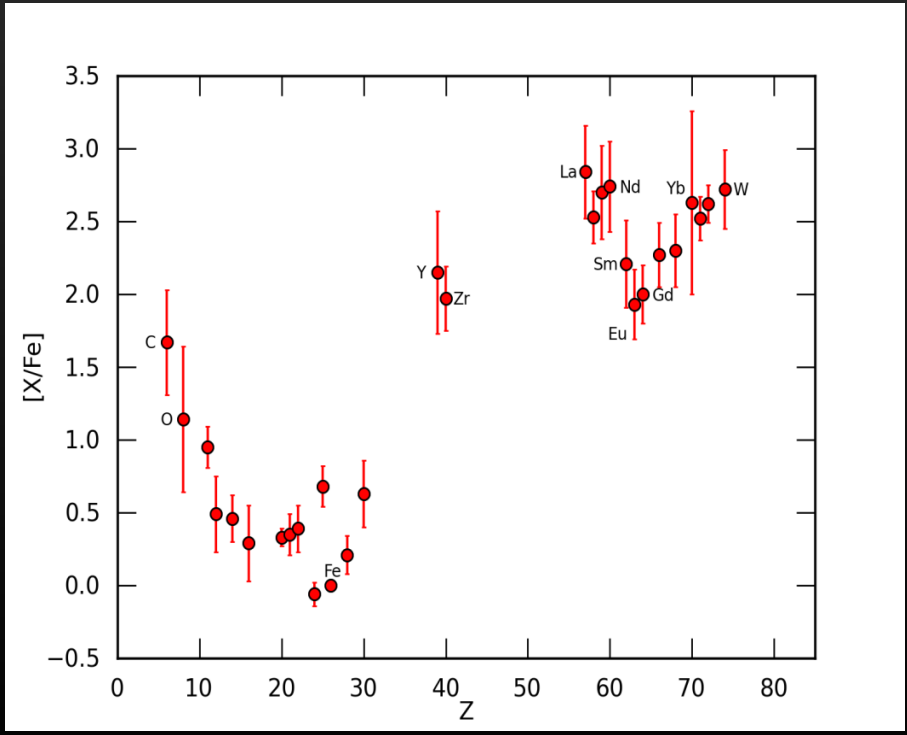
Atmospheric parameters (via Fe lines):

- Effective temperature
- Surface gravity
- Microturbulent velocity
- Metallicity [Fe/H]

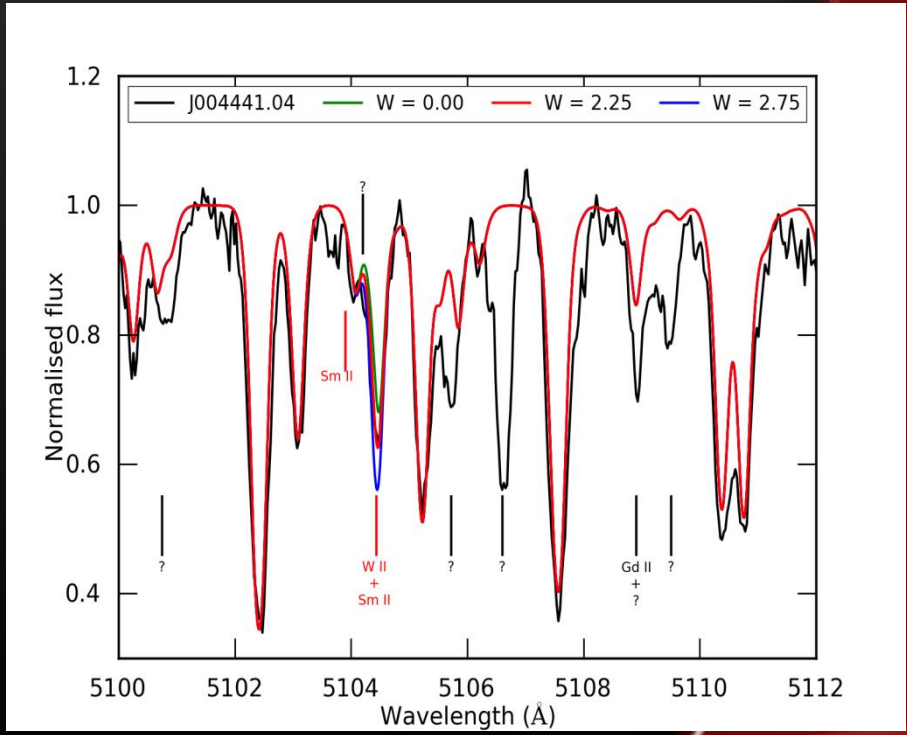
Abundance analysis

- Single lines
- Spectral synthesis for blends
- Element over Fe ratio shows enrichment
- Low metallicity: [Fe/H] = -1.3

De Smedt et al, 2012



Element over Fe ratio

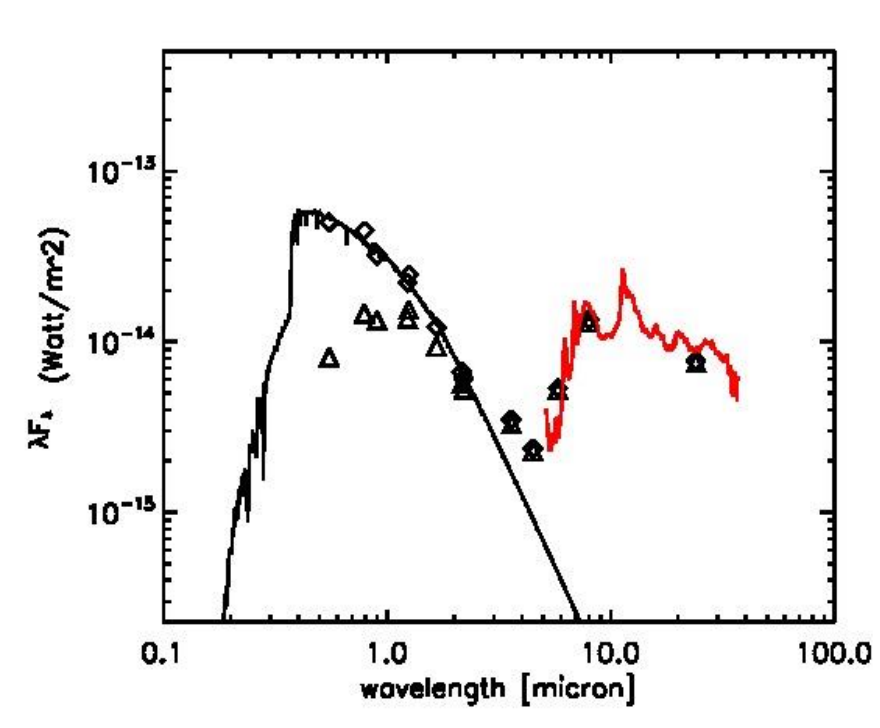


Spectral synthesis

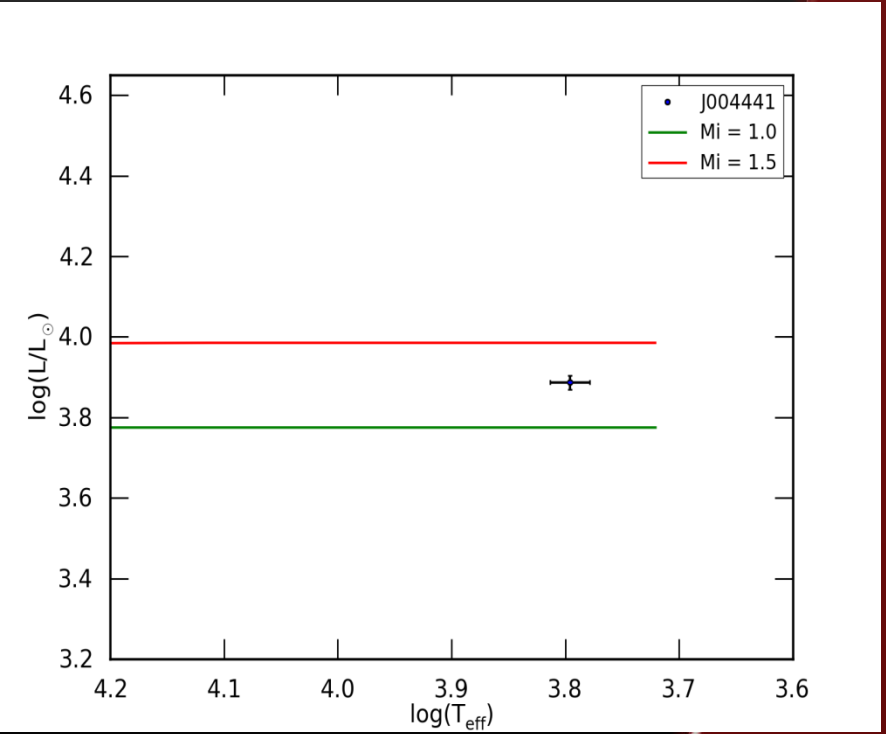
SED and initial mass

- SED gives luminosity
- Initial mass via theoretical post-AGB tracks (update needed)
- Low initial mass (±1.3 $M_{\odot}$)

De Smedt et al, 2012



SED



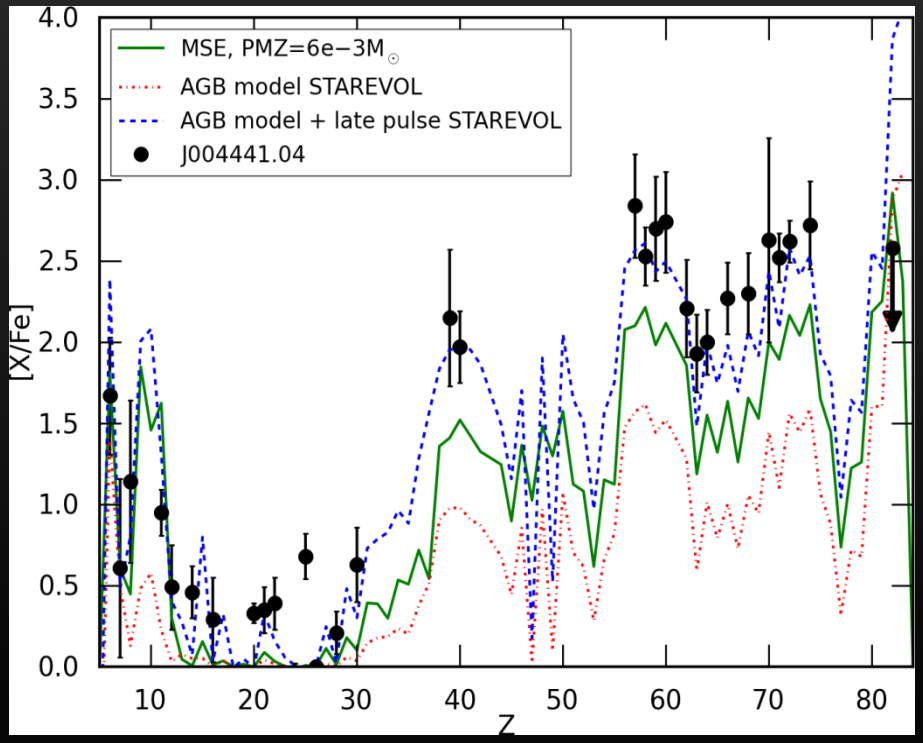
Initial mass determination
(Vassiliadis & Wood,1994)

Observations vs models

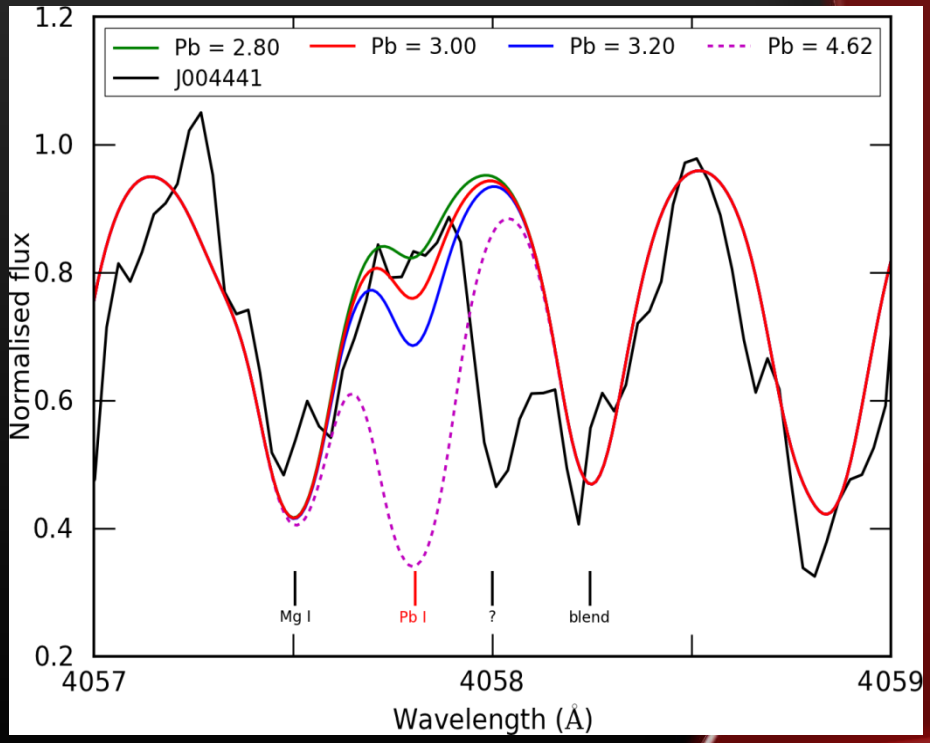
Upper limit Pb abundance via synthesis

Strong Pb discrepancy

De Smedt et al, 2014



Model predictions vs observations



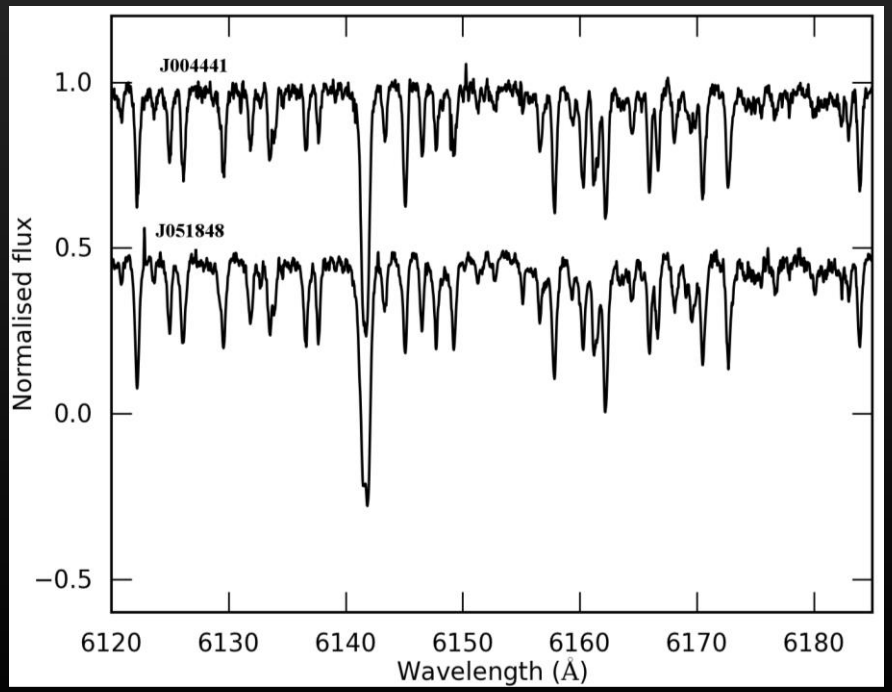
Pb abundance vs model

Other Pb results

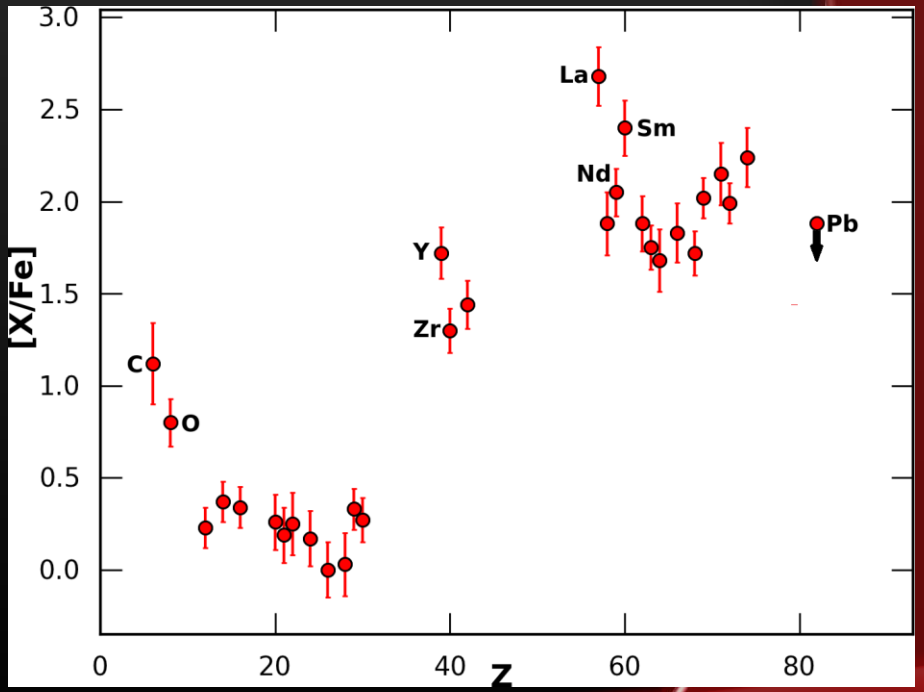
LMC star J051848.84-700247.0:

- spectral twin of SMC J004441
- Low-metallicity ([Fe/H] = -1.0)
- Low-mass (±1.3 $M_{\odot}$)
- Pb abundance upper limit
- No overabundance

De Smedt et al., in prep.



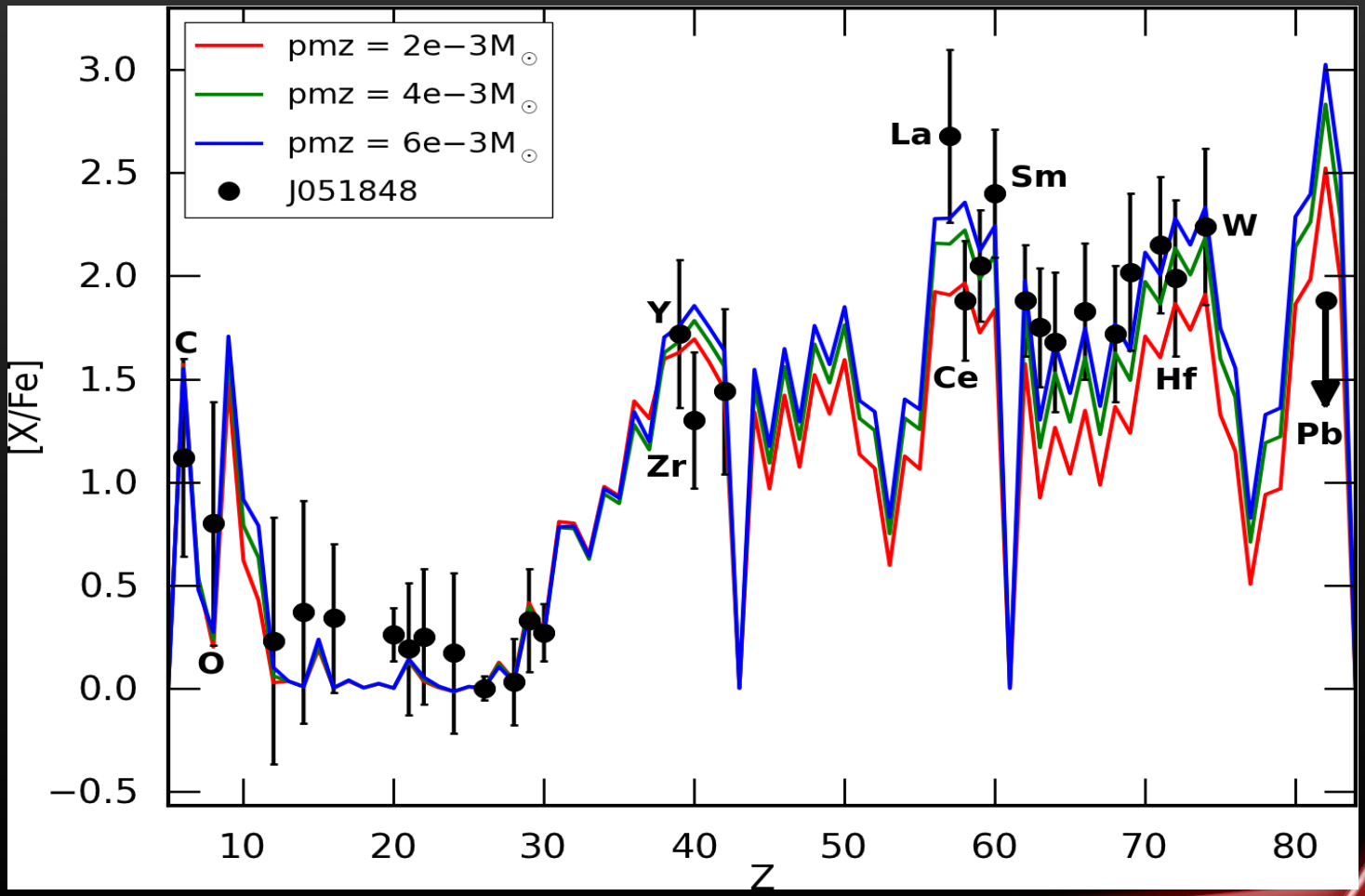
Spectra comparison



Element over Fe ratio

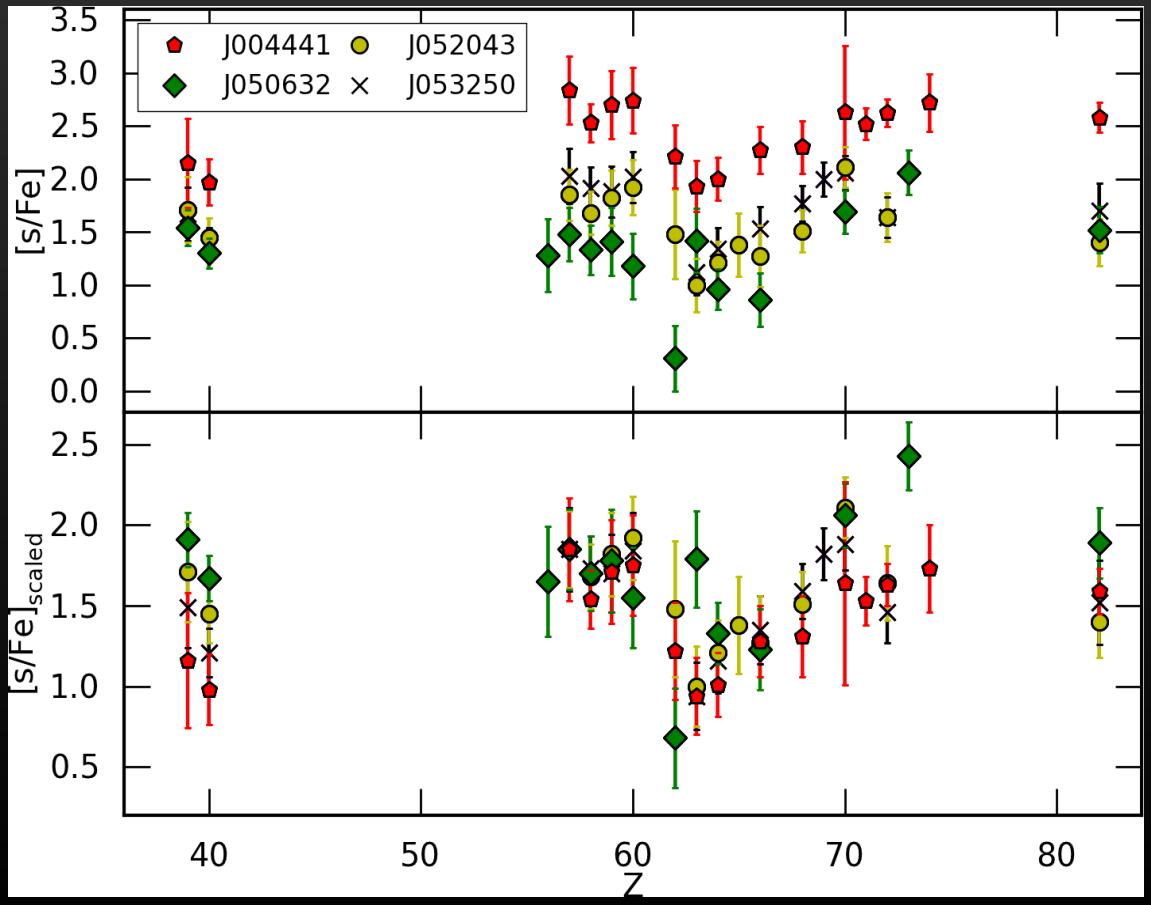
J051848 Pb vs models

Mount Stromlo models for 1.3 $M_{\odot}$ with [Fe/H] = -1.0



Three LMC objects

- Low-mass (< 1.5 $M_{\odot}$)
- Metal-poor ([Fe/H] ≈ -1.2)
- Pb abundance upper limits
- No Pb overabundance



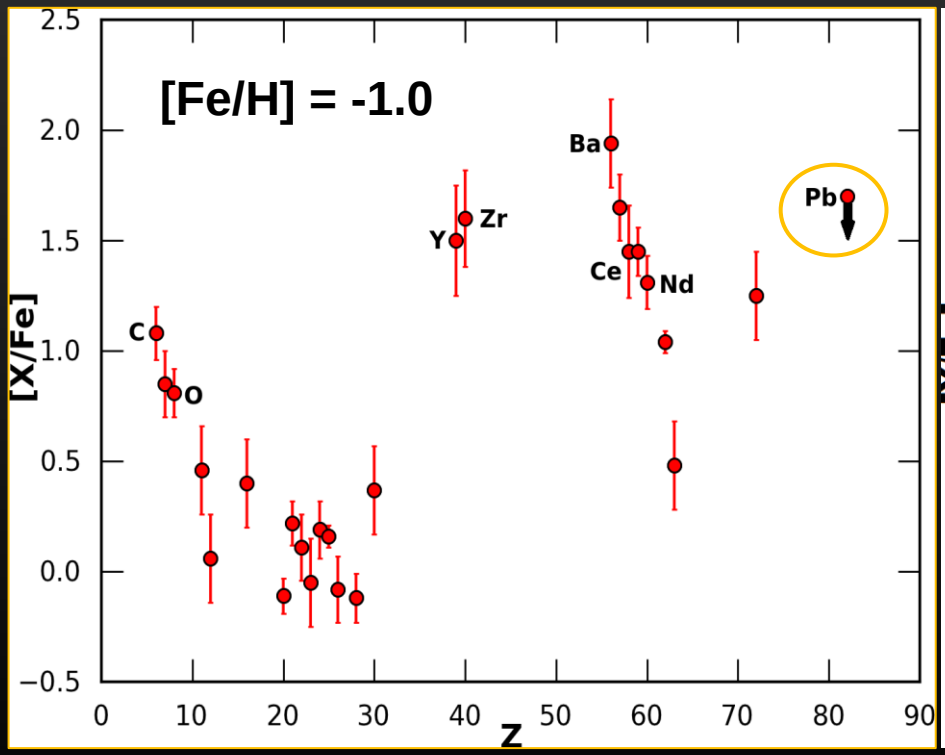
Talk by D. Kamath

Upper: [s/Fe] for different stars
Lower: [s/Fe] scaled to La (Z=57)

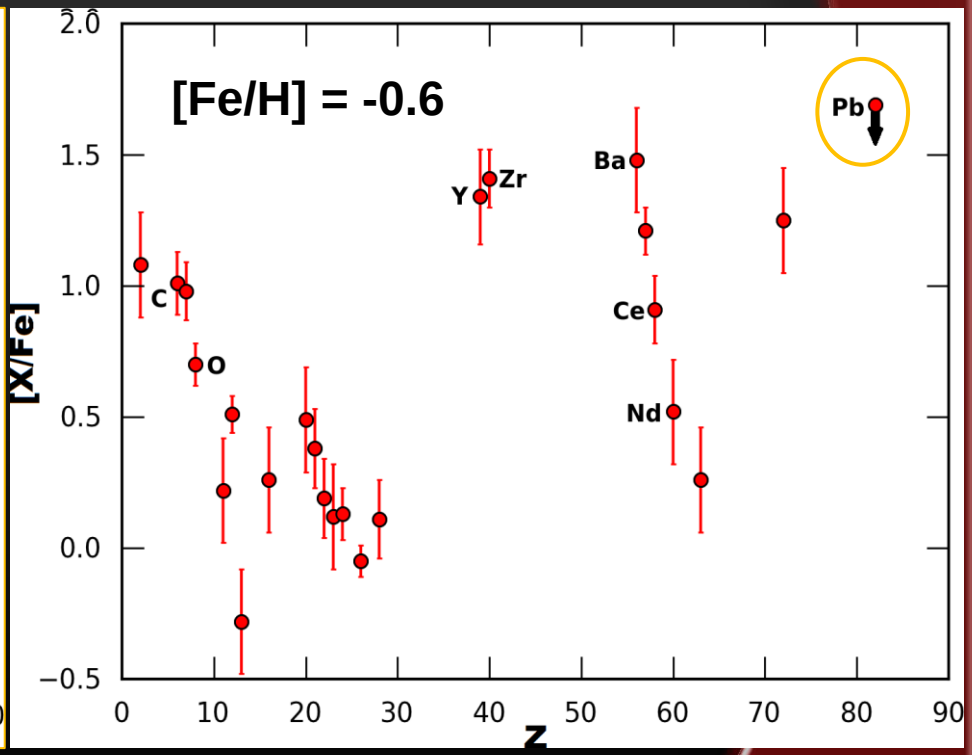
De Smedt et al, 2014

Preliminary: Galactic objects

- Part of sample of intrinsically enriched objects
- Range of metallicities but no distance
- Pb abundance upper limit



HD56126

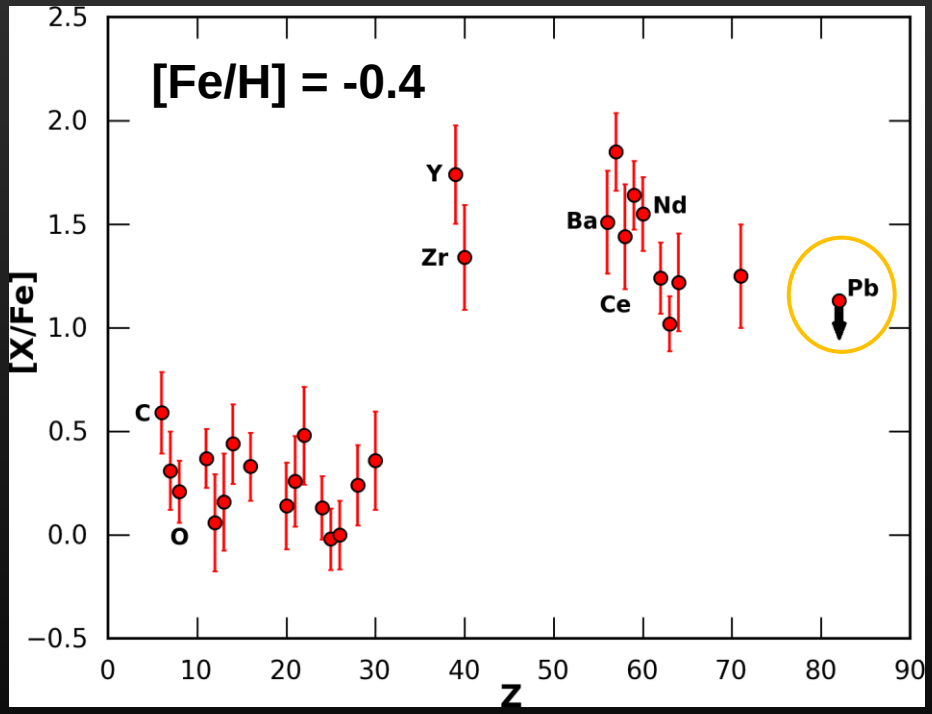


HD187885

Van Winckel et al., 2000

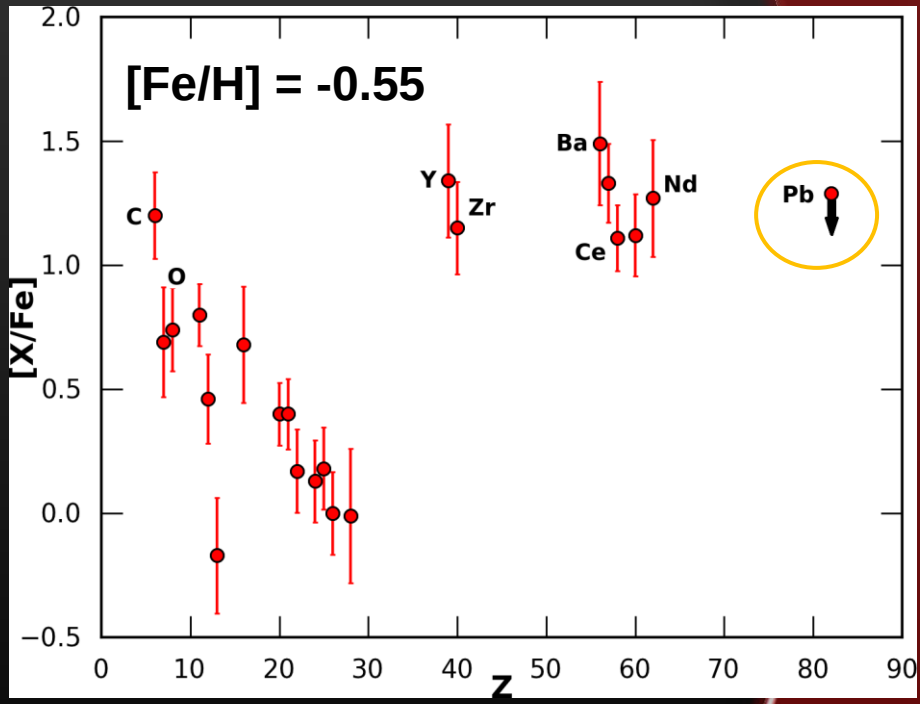
Preliminary: Galactic objects

IRAS 08143-4406



Reyniers et al. 2004

IRAS 14325-6428



Reyniers et al. 2007

General conclusion

From observations:

Current AGB models based on ^{13}C-pocket:

- diffusive overshooting
- base of convective envelope
- during third dredge-up

Problems reproducing low [Pb/Fe] in metal-poor stars

Increase sample of studied objects: statistics

Possible solutions

Explore alternative processes to explain abundance profiles:

- New mixing algorithms

  (^{13}C-pocket mass and distribution)

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- Effect rotational shear (see talk S. Cristallo)

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- Effect of internal gravity wave mixing

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- …

Conclusions

- No Pb overabundance in studied intrinsically enriched post-AGB stars
- Study alternative processes for ^{13}C-pocket formation
- Increase sample of studied intrinsically enriched post-AGB stars

Thank you

Questions?