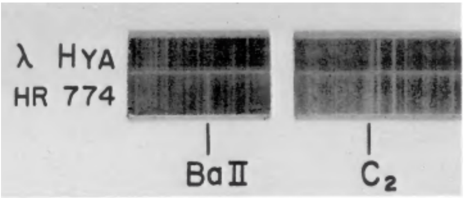
Tracing the slow neutron capture process in AGB stars using Barium star abundances

Borbála Cseh
Konkoly Observatory

SNAQ, 10 November 2021

Ba stars

- peculiar G–K spectral type, [Fe/H] > –1 dex
- strong spectral features: carbon molecular bands + s-process elements (e.g. Ba)
  → synthetised inside AGB stars
- origin of overabundance? intrinsic or extrinsic?



(Bidelman & Keenan 1951)

→ ***Absolute abundance*** $\log A(X) = \log_{10}\left(\frac{N_X}{N_H}\right) + 12$

→ ***Abundance ratio*** $[X/Y] = \log_{10}\left(\frac{N_X}{N_Y}\right)_* - \log_{10}\left(\frac{N_X}{N_Y}\right)_\odot$

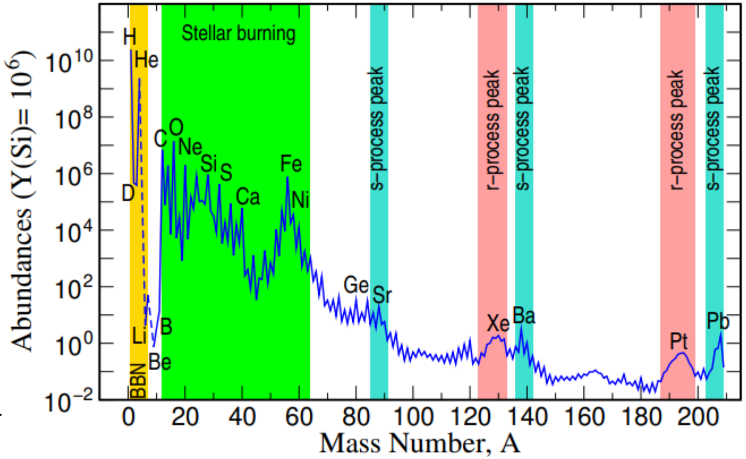
→ **The Sun: [X/Y] = 0**

Ba stars

- not yet evolved to the AGB phase
- RV variation (McClure+ 1983, ...), UV excess (Böhm-Vitense+ 2000)
  → binary systems, now WD companion
  → mass transfer, pollution from a former AGB companion
  → test: AGB s-process nucleosynthesis

s process

- s process: during TP-AGB phase
- peaks at Sr (1. peak), Ba (2. peak), Pb (3. peak)
- how to measure s-process efficiency?
  → ratio of heavy (2. peak) and light (1. peak) s elements:
  [hs/ls] → ratio: elimination of dilution effects
  → s=? hs=? ls=?
- ls: Sr, Y, Zr
  hs: Ba, La, Ce, Nd



Cowan+ 2021

sample stars

- de Castro+ (2016):
  - 182 giant Ba stars (certain, candidate)
  - high resolution spectra (FEROS, R = 48000)
  - wide range in T_{eff} (4100–5400 K), metallicity
- Ba star: if [s/Fe] ≥ 0.25 dex, here s = La, Ce, Nd, Y, Zr
  → 13 stars rejected → 169 stars
- average [hs/ls], estimated error → separate elements + errors
  [hs/ls] → [Ce/Y], ...

AGB models

- final surface abundances, [s/Fe] ≥ 0.25 dex
- wide range of metallicities, masses, different ^{13}C pocket size: to produce s-process elements
- FRUITY + Monash + NuGrid

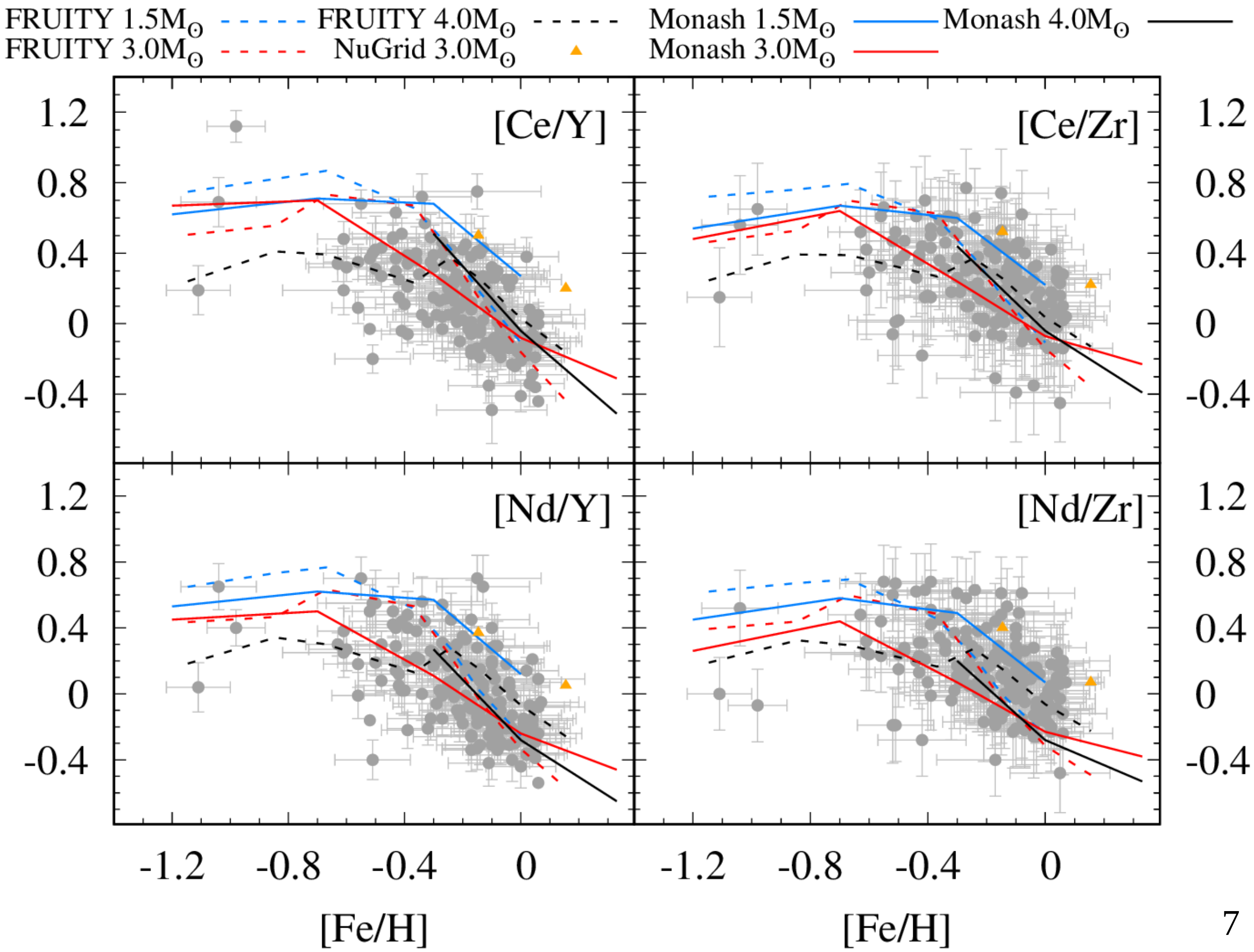
Cristallo+ 2016,
Cristallo+ 2015,
Straniero+ 2014,
Piersanti+ 2013,
Cristallo+ 2011,
Cristallo+ 2009

Karakas+ 2018,
Karakas & Lugaro 2016,
Fishlock+ 2013,
Lugaro+ 2012

Pignatari+ 2016,
Battino+ 2016

model comparison

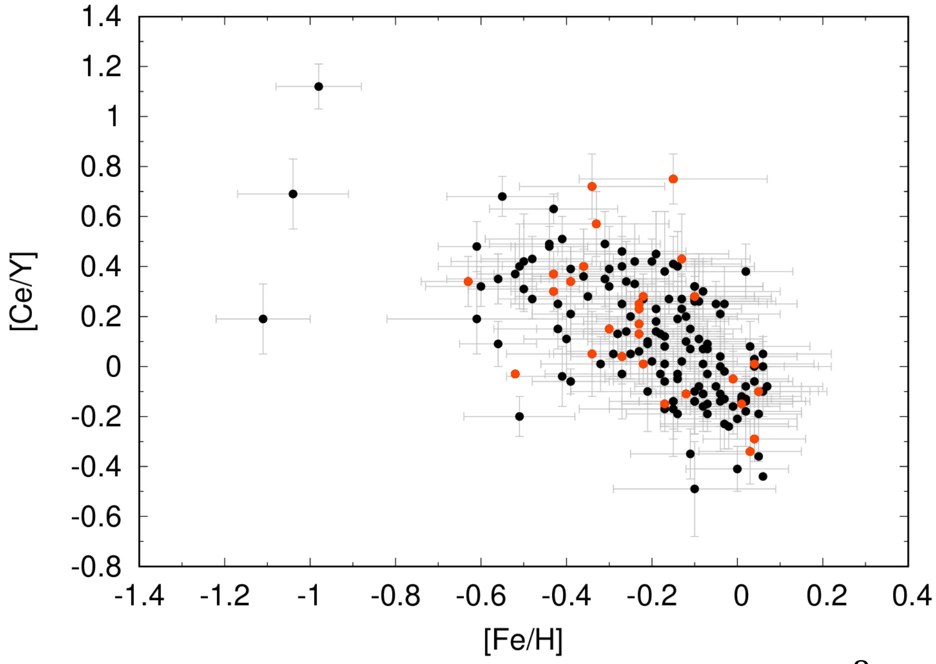
- models in agreement with the data trends



(Cseh+ 2018)

comparison of individual stars

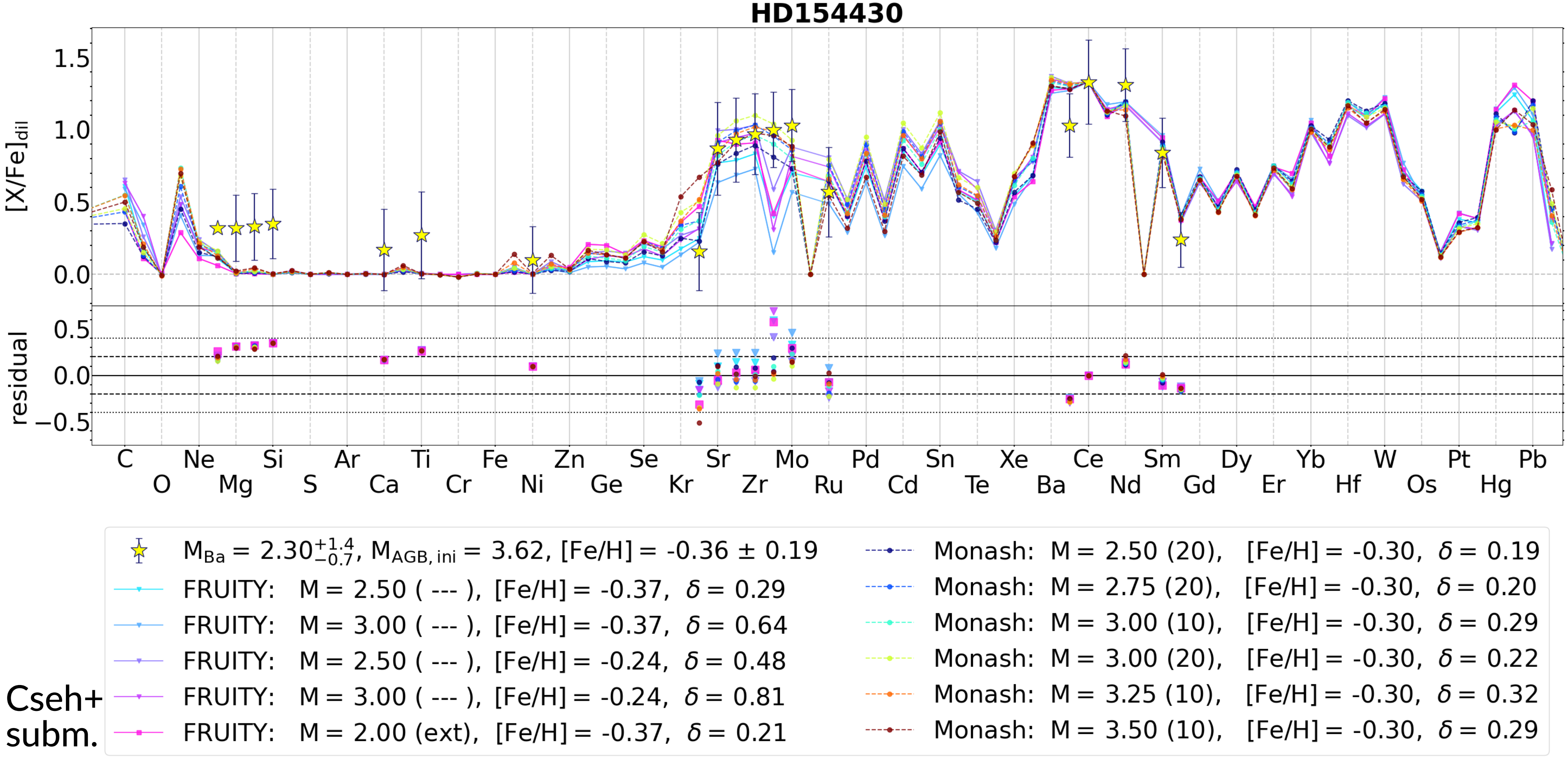
- 28 stars from the sample (de Castro+ 2016)
  → orbits + masses (Ba + $AGB_{initial}$) (Jorissen+ 2019)
- new elemental abundances: Rb, Sr, Nb, Mo, Ru, Sm, Eu + new La values (improved atomic data + hfs included) (Roriz+ 2021a,b)



comparison of individual stars

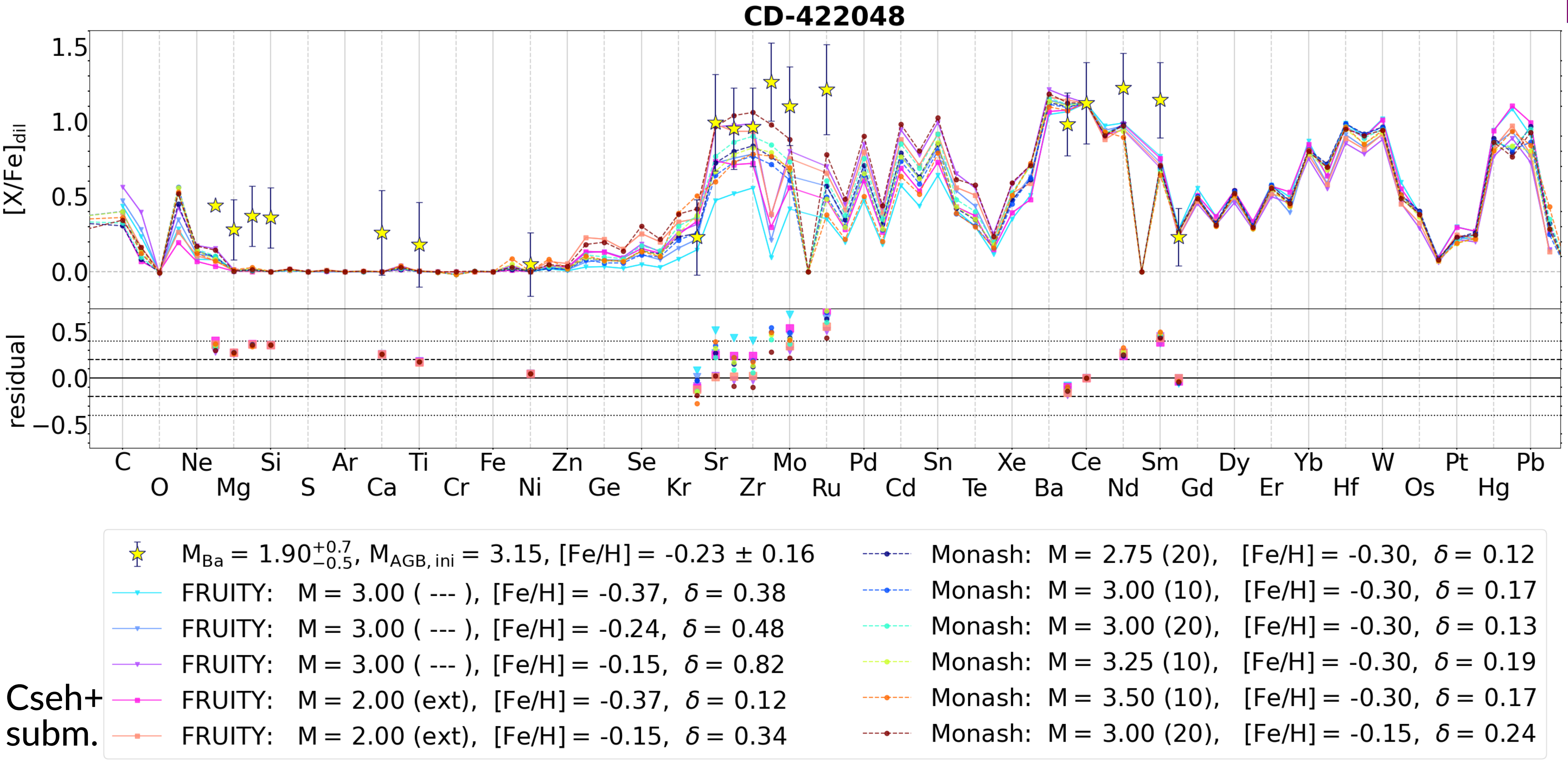
- all giants (with convective envelope)
  → AGB mass carried to the secondary and mixed
  → model comparison with dilution (δ)
- δ: to match [Ce/Fe], limit: δ < 0.9 (< 90% of the AGB envelope carried to the Ba star's surface)
- models:
  - different ^{13}C pockets
  - metallicity range: Ba star's [Fe/H] +/- err

examples - OK



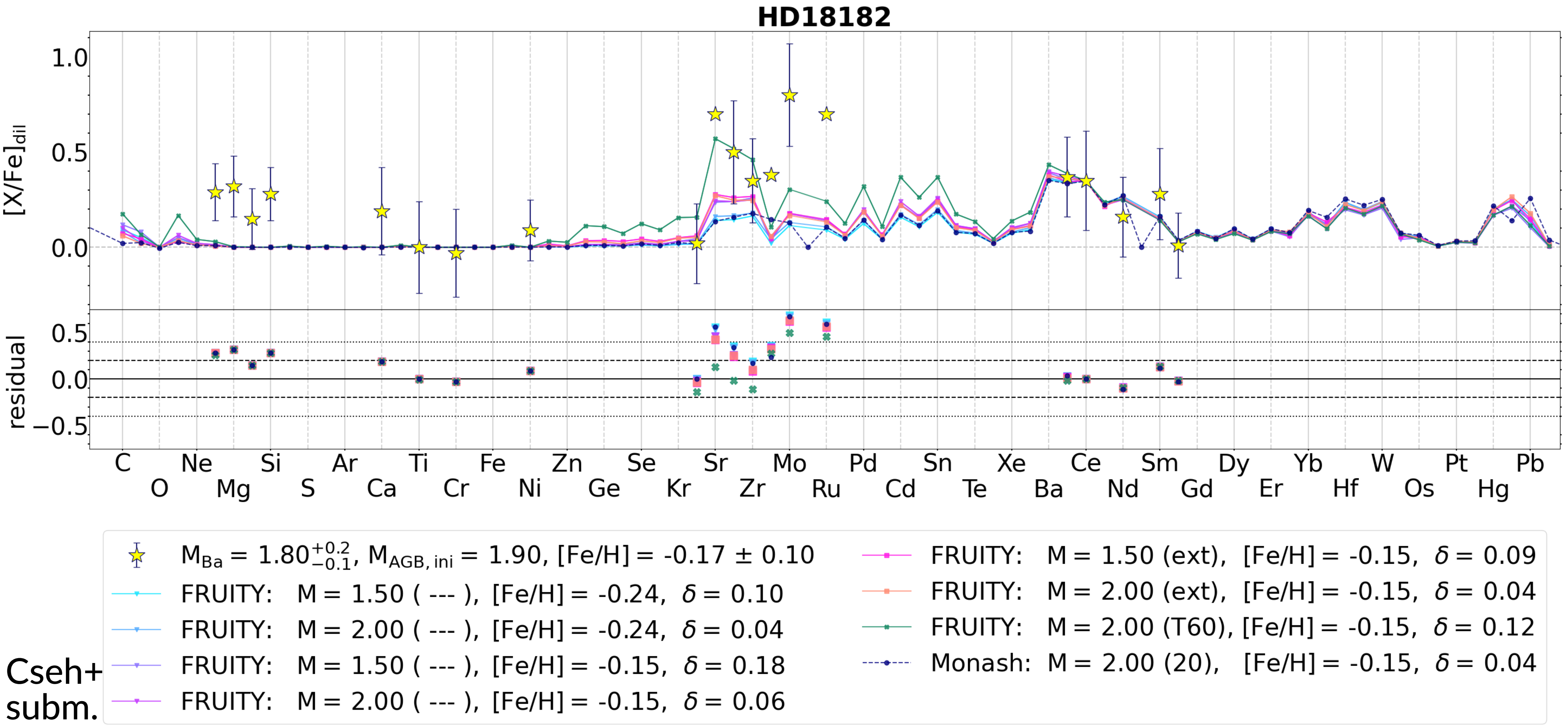
Cseh+
subm.

examples



Cseh+
subm.

examples – high first peak



Cseh+ subm.

comparison of individual stars

- out of 28 stars:
  - good match with 25 stars (some with higher independently derived AGB_{ini} masses)
    → 16 stars with higher Nb, Mo, Ru and/or Nd, Sm
  - 3 with higher first s-process peak, low mass AGB_{ini} (< 2 M_{sun}): these models cannot reproduce it!
    → different neutron density?
    → can a new process of nucleosynthesis be identified and added to the model calculations?

Cseh+ subm.

summary

- Ba star polluters: low mass AGBs (~2–3 M_{sun}, with ^{13}C as main neutron source)
- good match with 25 stars, 3 with higher first peak
- more stars coming with the same abundance pattern: using machine learning techniques
(den Hartogh+ in prep.)
- include also other model sets

summary

- Ba star polluters: low mass AGBs (~2–3 M_{sun}, with ^{13}C as main neutron source)
- good match with 25 stars, 3 with higher first peak
- more stars coming with the same abundance pattern: using machine learning techniques (den Hartogh+ in prep.)
- include also other model sets

Thank you for your attention!