Stellar Beryllium Abundances

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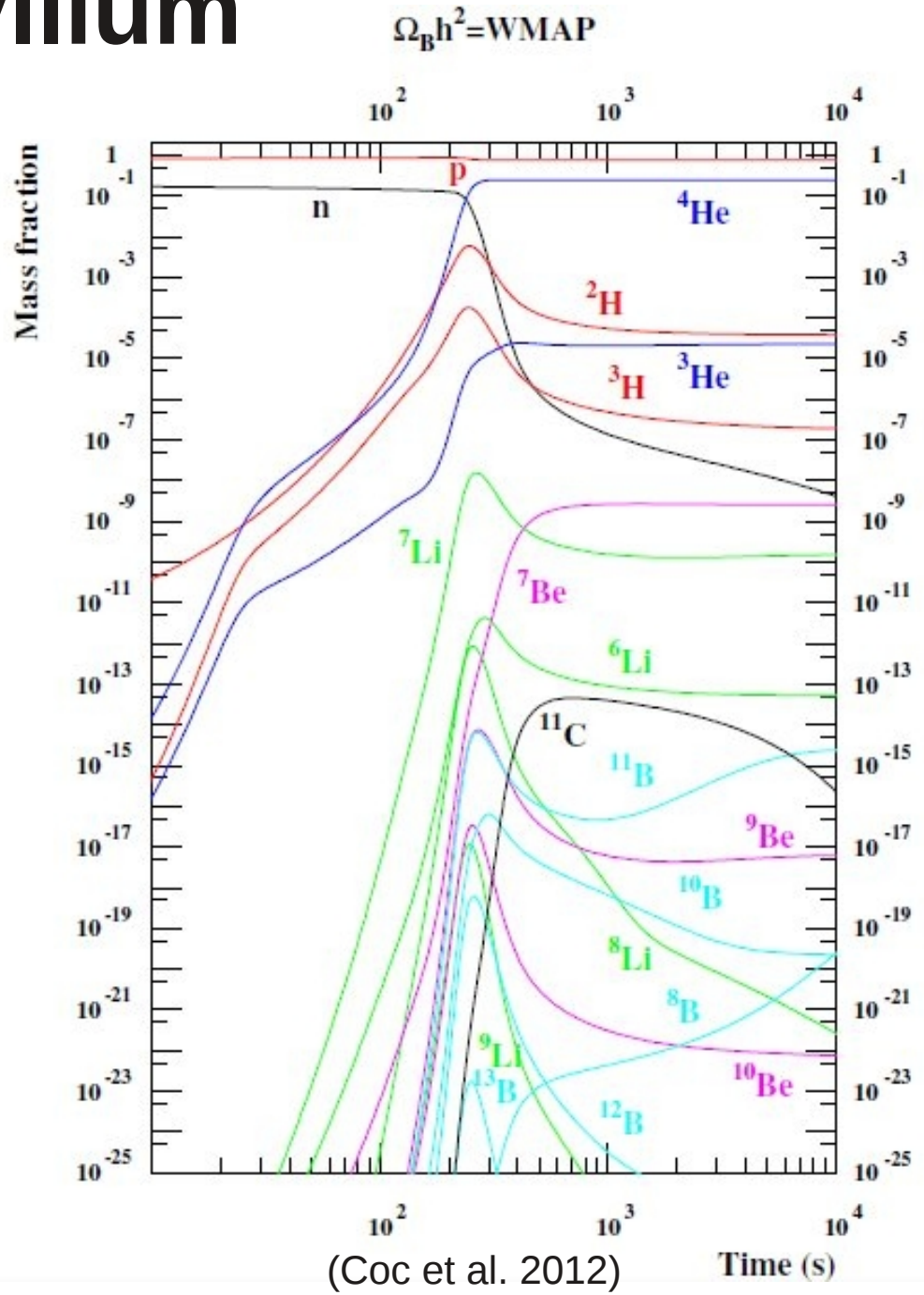
TOPICS

- How Be is formed and destroyed
- Measuring Be abundances
- Science with Be abundances:
  Metal-poor stars
  Globular clusters
  Evolutionary mixing
- Be and CUBES

The nucleosynthesis of beryllium

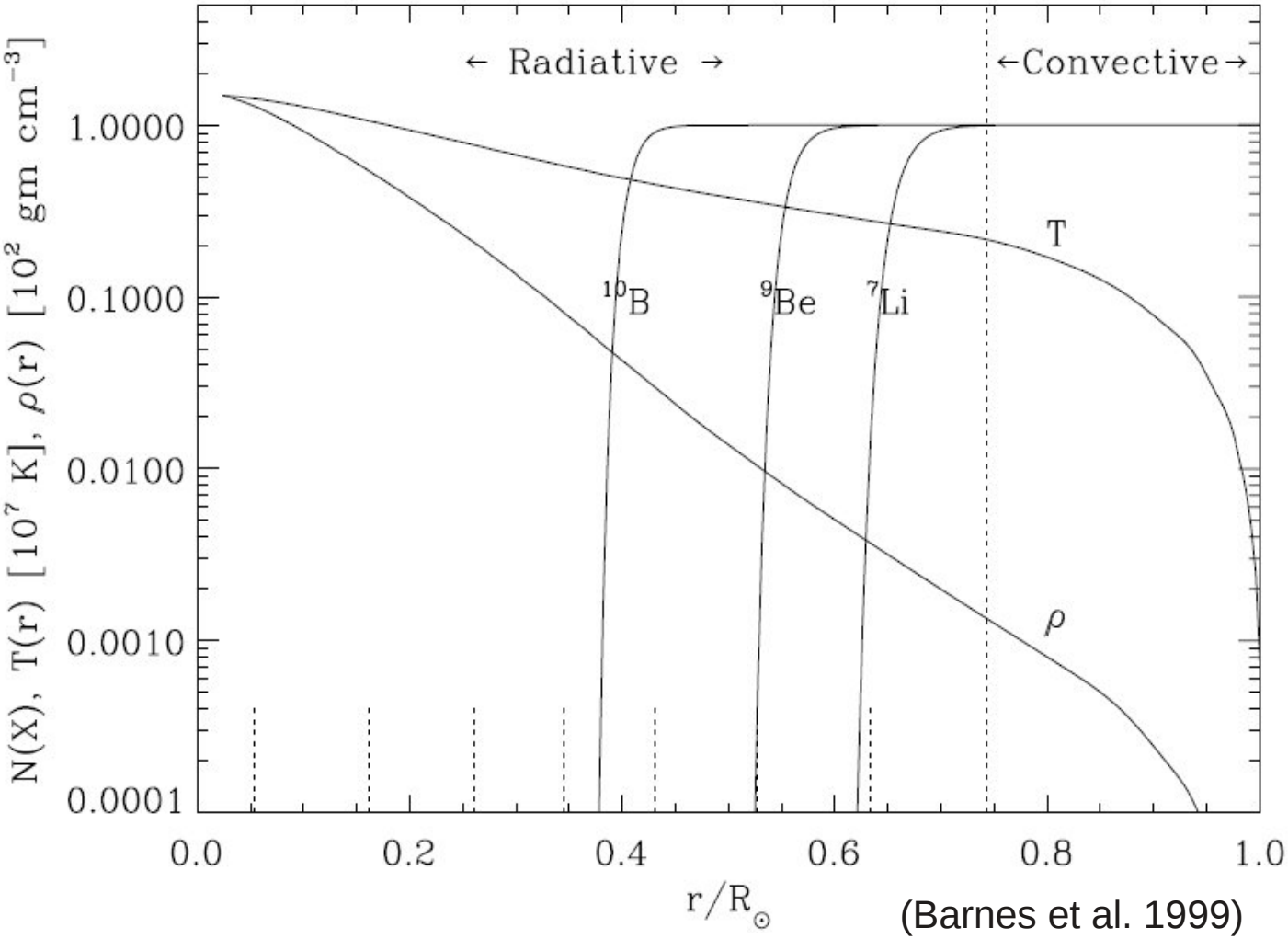
- Primordial nucleosynthesis?
- Be production not significant
- No stable nuclei with mass numbers 5 and 8!
- $^{7}Li(t,n)^{9}Be$
- $^{7}Li(d,\gamma)^{9}Be$



(Coc et al. 2012)

The nucleosynthesis of beryllium

- Stellar nucleosynthesis?
- Be is fragile and destroyed!
- $T > 3.5 \times 10^6$ K
- $^9Be(p,\alpha)^6Li$
- $^9Be(p,d)2^4He$



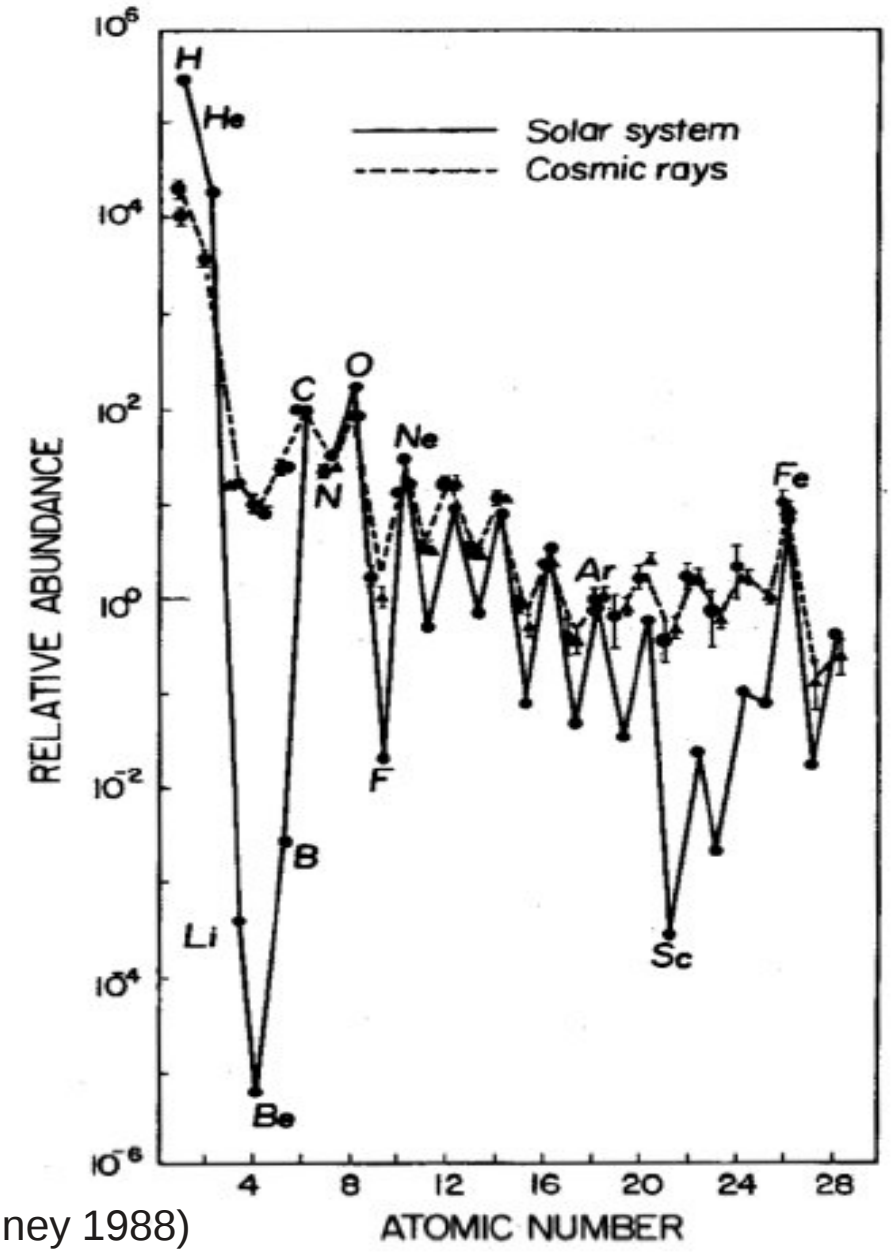
(Barnes et al. 1999)

The nucleosynthesis of beryllium

- Cosmic ray spallation!
  (Reeves et al. 1970, Meneguzzi et al. 1971)

- Cosmic rays + ISM material
- Fission of heavier nuclei (CNO)

- p + $^{16}O \rightarrow {}^{9}Be$ + ...
- α + $^{16}O \rightarrow {}^{9}Be$ + ...
- p + $^{12}C \rightarrow {}^{9}Be$ + ...
- α + $^{12}C \rightarrow {}^{9}Be$ + ...



(Rolfs & Rodney 1988)

Be in the Galaxy

How the abundance of Be evolves with time?

- Cosmic ray spallation:

1. accelerated protons/α-particles on CNO of the medium (direct process)

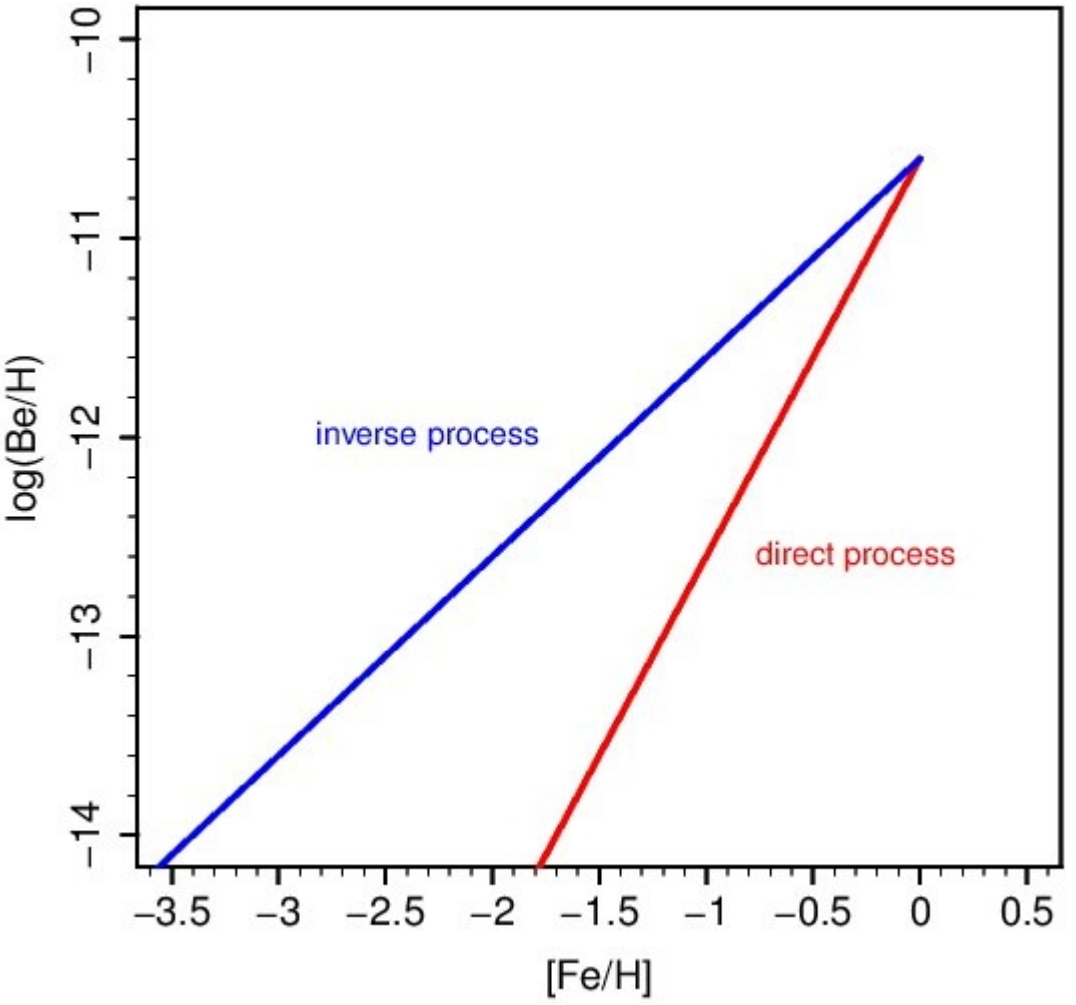
or

2. accelerated CNO on protons/α-particles of the medium (inverse process)

Be in the Galaxy

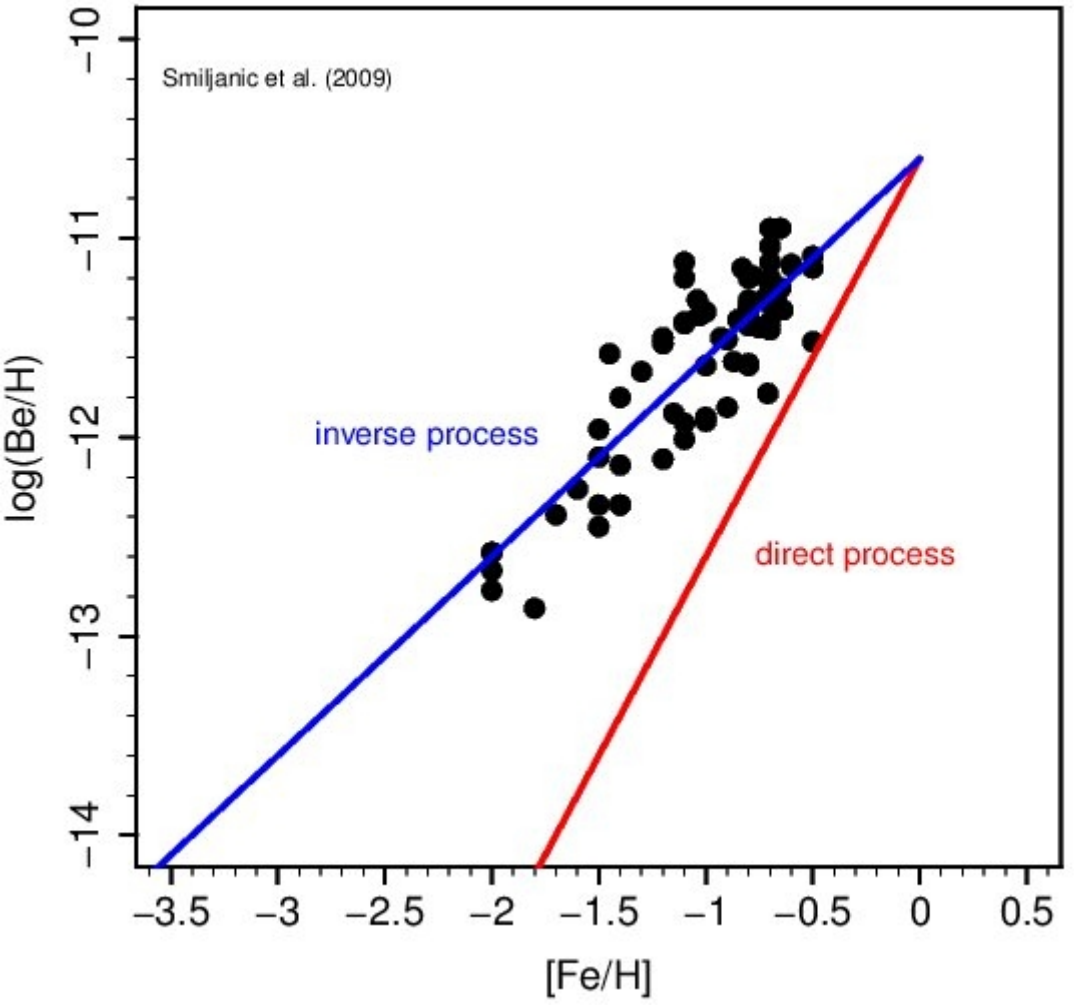
- Direct process:
  Be is a secondary element

- Inverse process:
  Be is a primary element



Be in the Galaxy

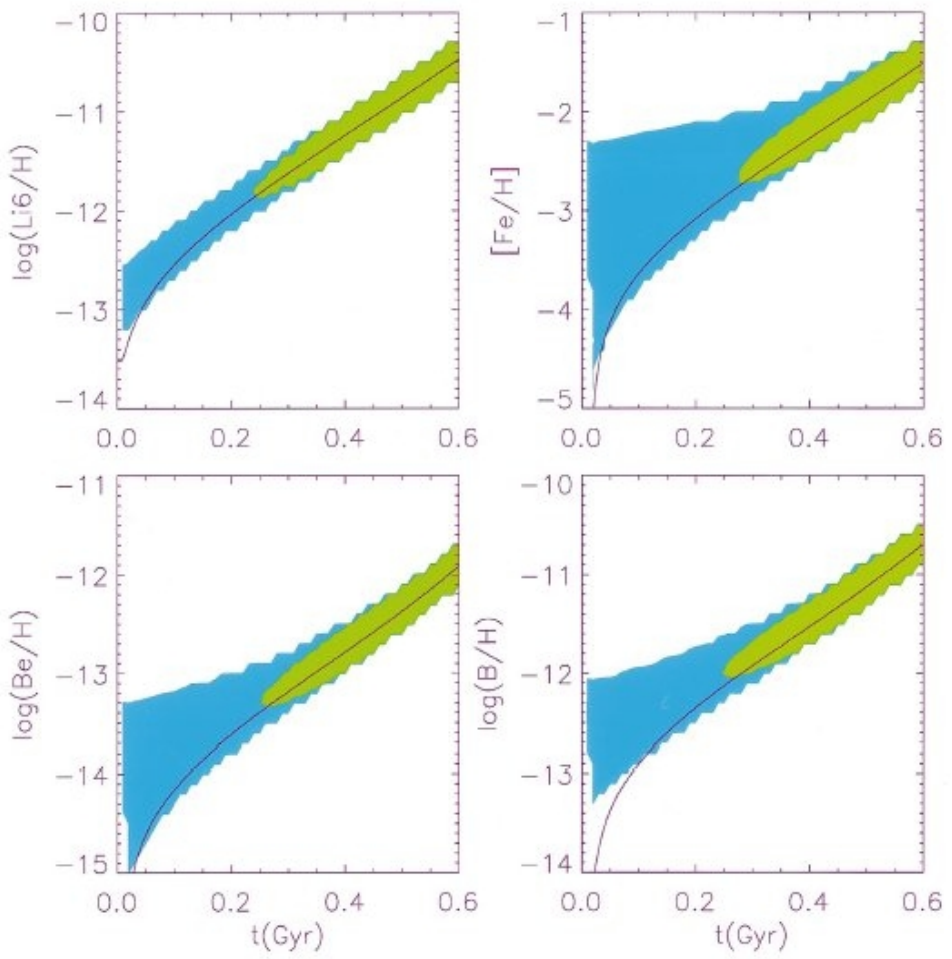
- Direct process:
  Be is a secondary element
- Inverse process:
  Be is a primary element
- CNO nuclei are accelerated
  (Duncan et al. 1992)



Be in the Galaxy

- Be production is widespread
- Star formation is disperse and inhomogeneous

Be in the Galaxy



(Suzuki & Yoshii 2001)

- Be production is widespread
- Star formation is disperse and inhomogeneous
- Be abundances more homogeneous than other elements
- Better correlation with time

Properties of Be

- Single stable isotope: ^{9}Be
- Only produced by cosmic-ray spallation
- Produced by the inverse process
- Widespread Galactic production
- Might be a good indicator of time
- Inside stars it can only be destroyed

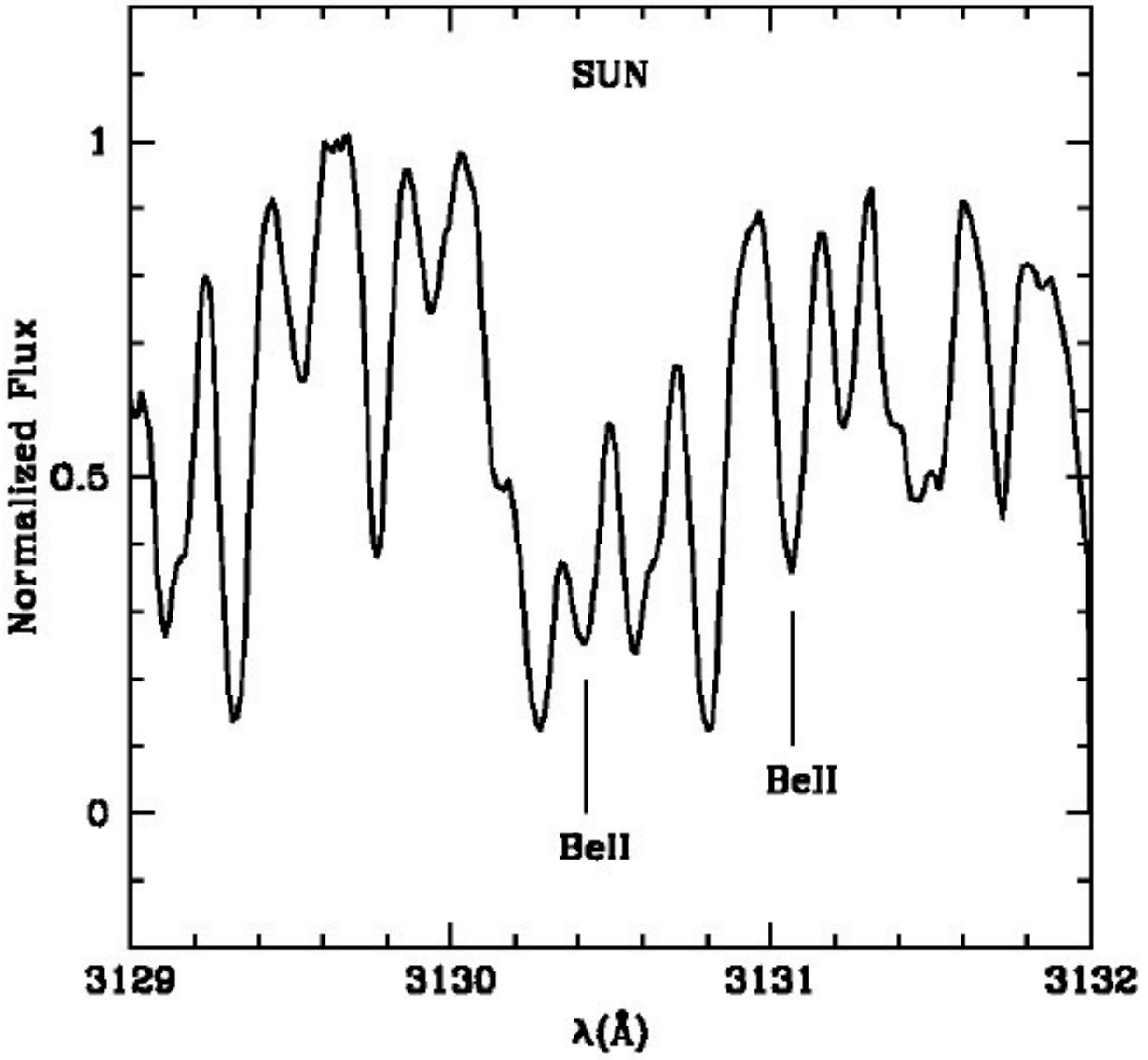
Science with Be

23 refereed papers with ESO data about Beryllium:
(515 citations as of Oct. 2013)

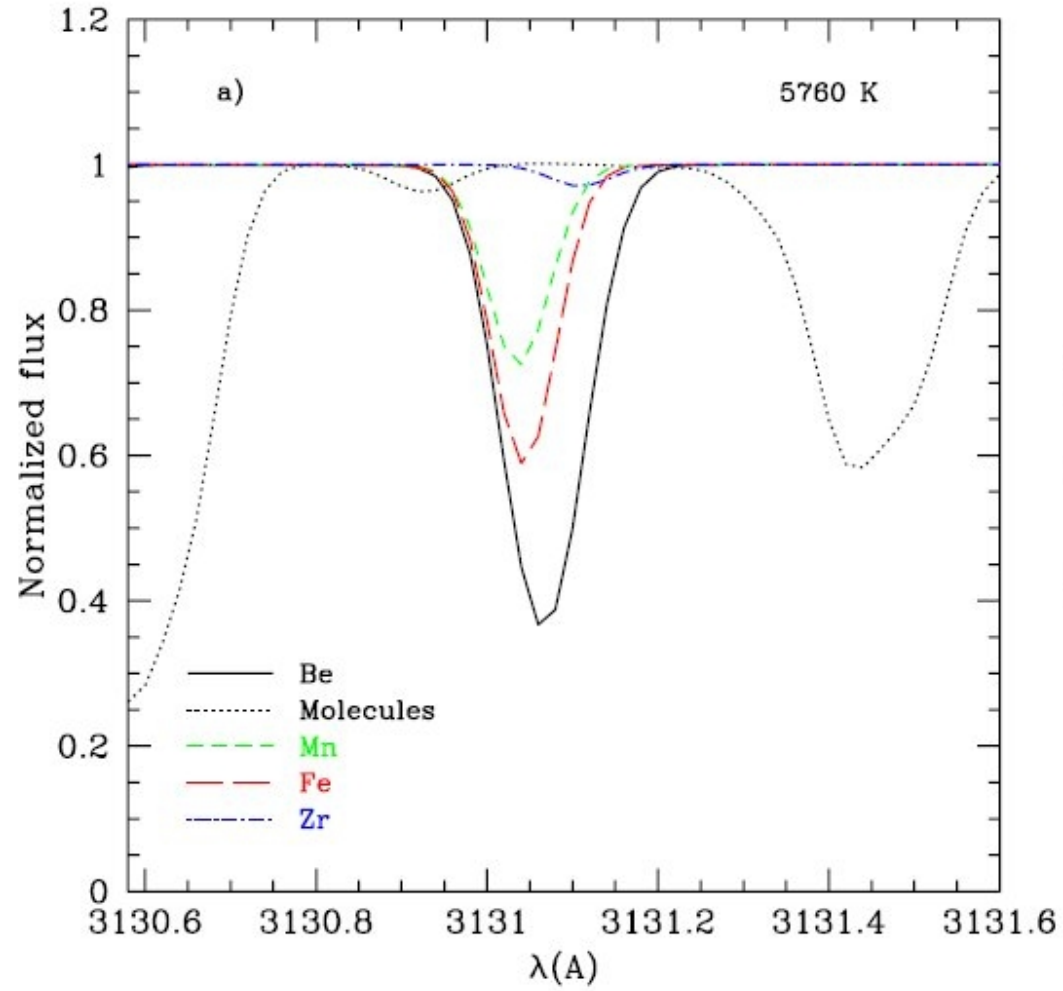
- Evolutionary mixing
- Evolution of Be in the Galaxy
- Globular clusters
- Metal-poor stars
- Lithium-rich stars and other peculiar objects
- Planet-host stars

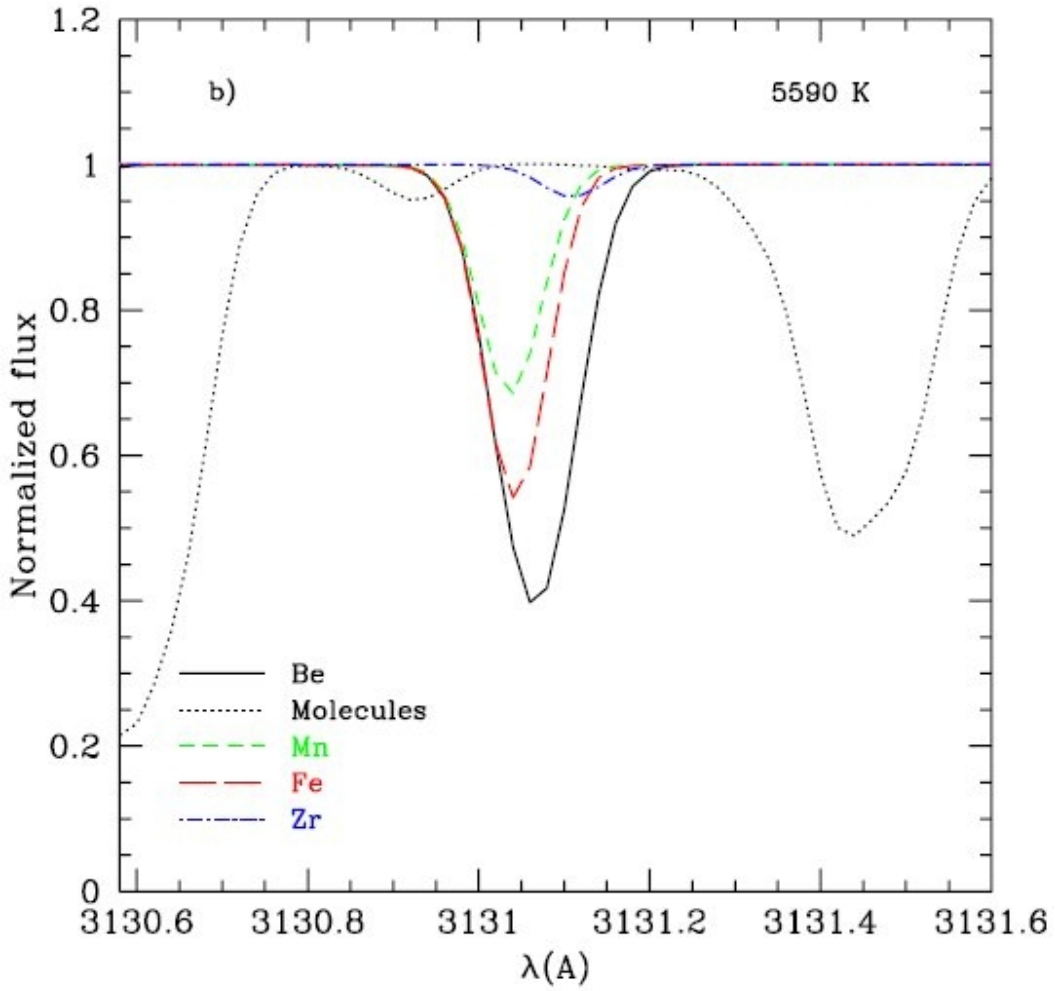
Be spectral lines

- Resonance lines at 3130 and 3131 Å
- Close to the atmospheric cut-off
- Heavily blended region



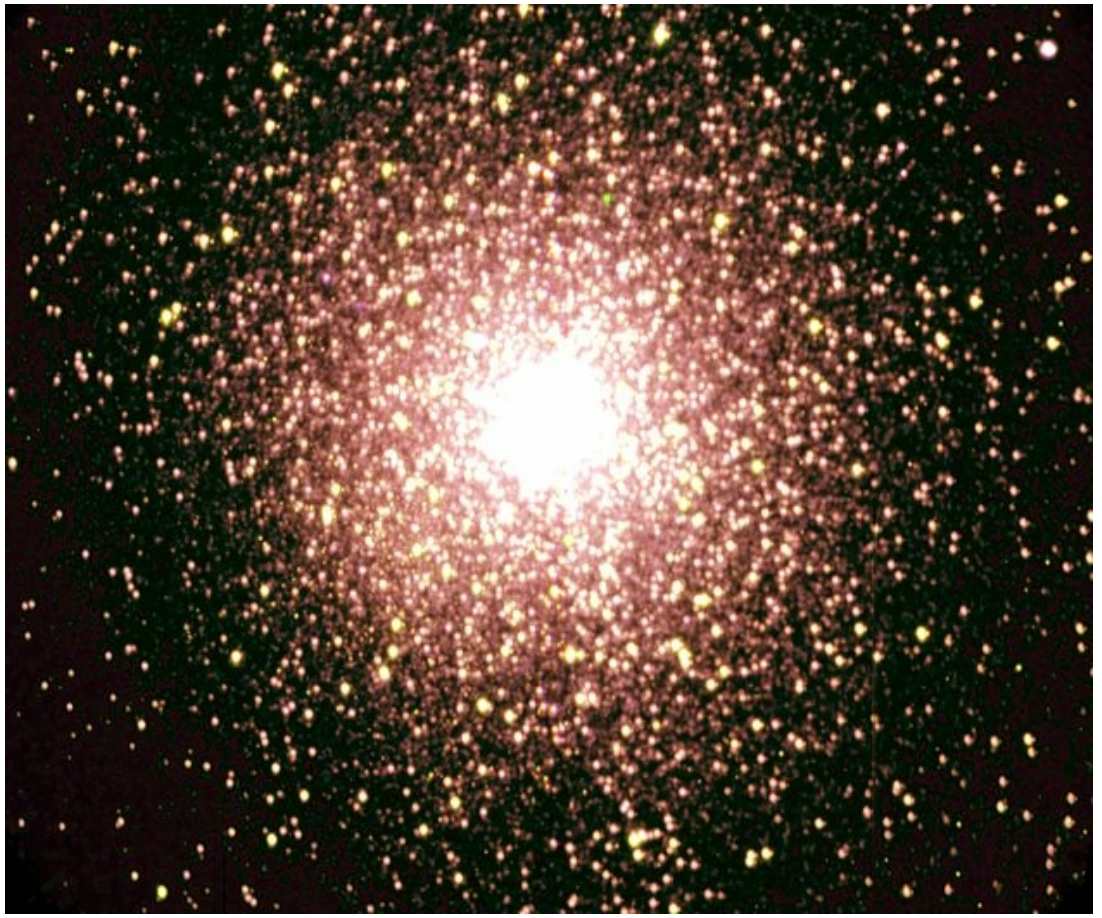
Be spectral lines





(Smiljanic et al. 2011)

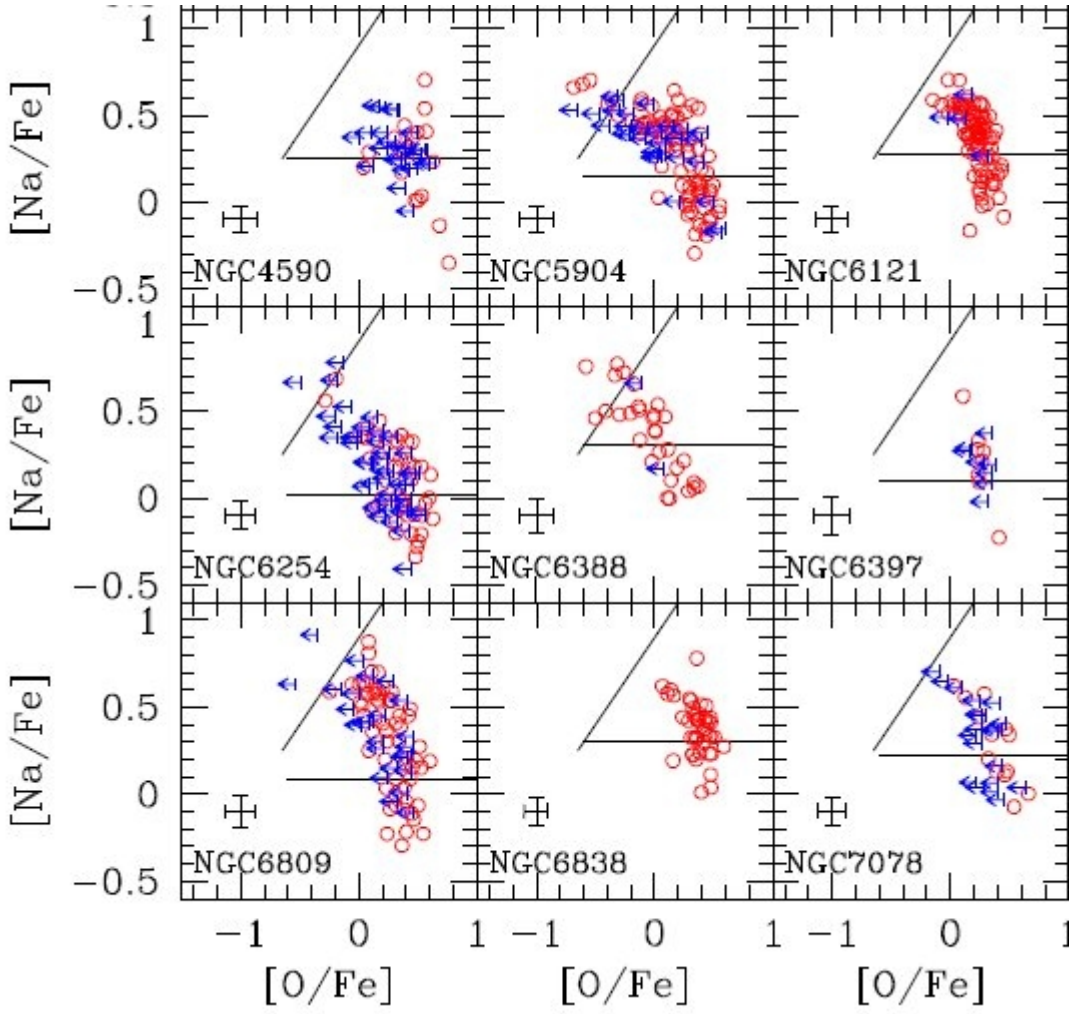
Globular Clusters



(47 Tuc - credits: SALT)

- Host multiple populations
- 2nd generation contaminated by proton-capture processed material
- From AGBs or massive rotating stars

Globular Clusters



(Gratton et al. 2012)

- NeNa Cycle: T ~ 40×10^6 K
- MgAl Cycle: T ~ 70×10^6 K

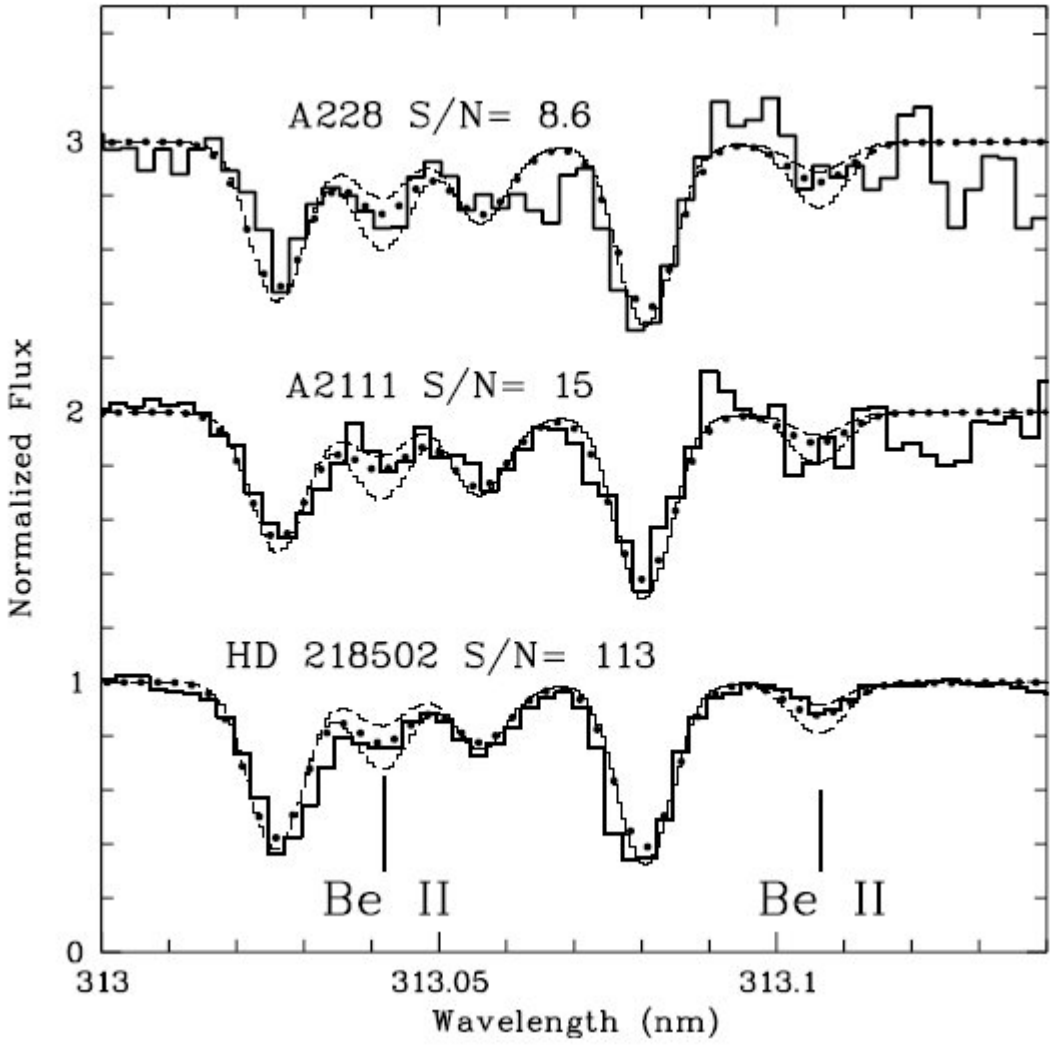
- Li destroyed: T ~ 2.5×10^6 K
- Be destroyed: T ~ 3.5×10^6 K

- Li can be produced by AGBs

- Be not produced in stars

Globular Clusters

2nd generation stars should have diluted Be.

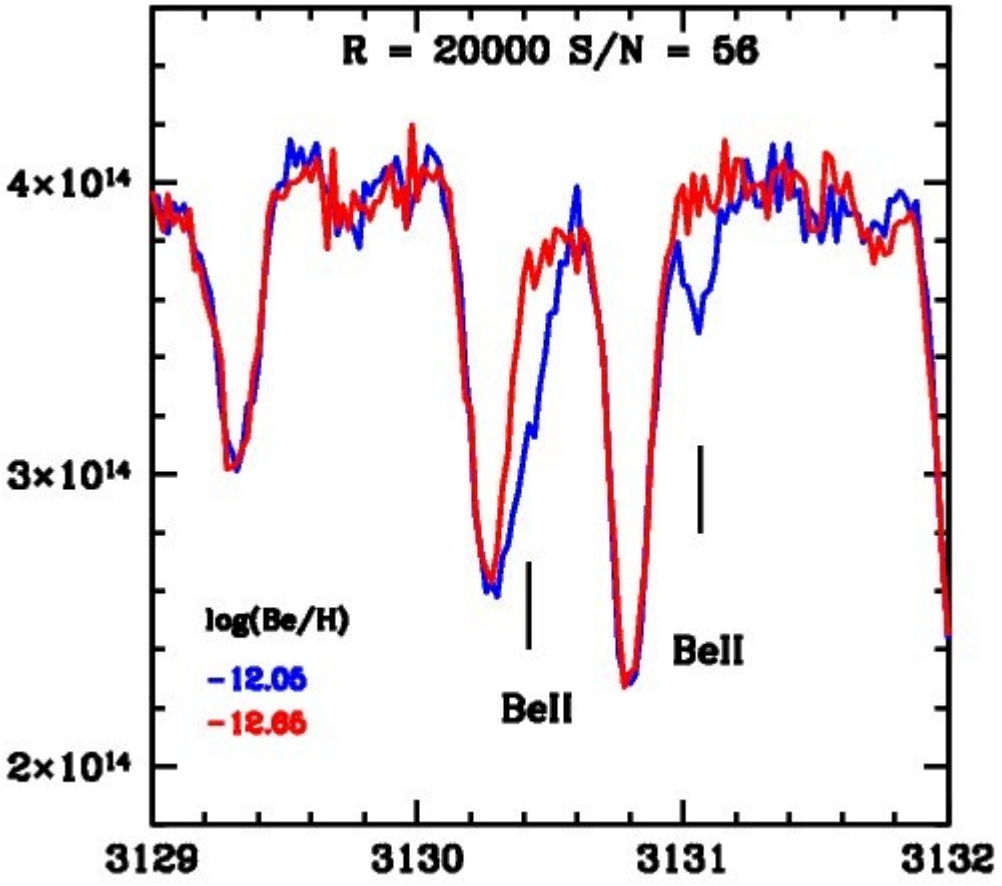


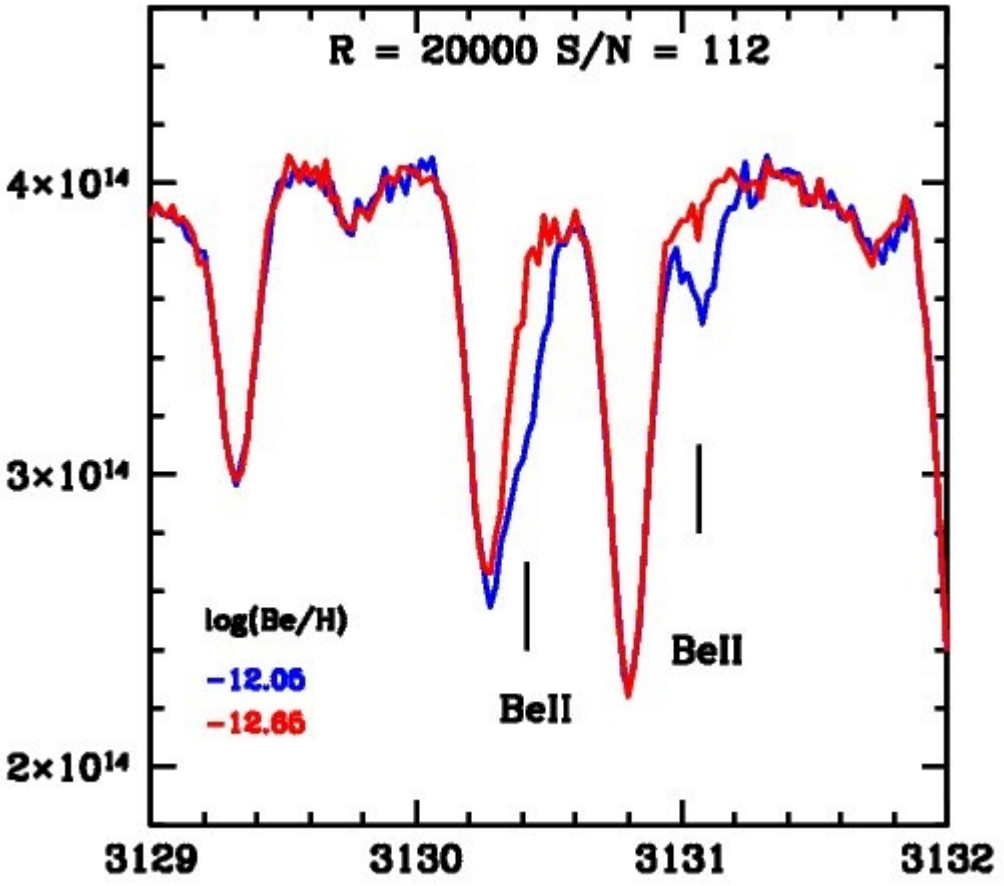
(Pasquini et al. 2004)

- NGC 6397
- A2111 → 1st generation
- A228 → 2nd generation
- Both seem to have Be at the same level!

Globular Clusters and CUBES

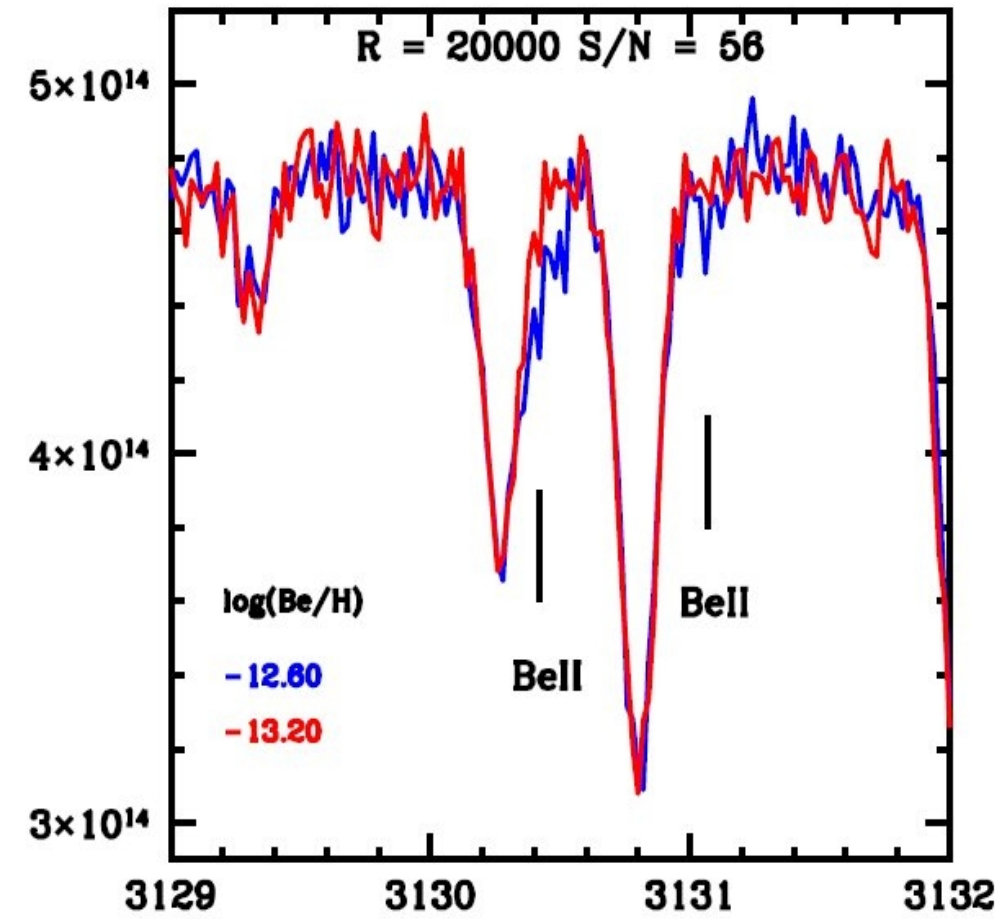
Turn-off stars in NGC6752

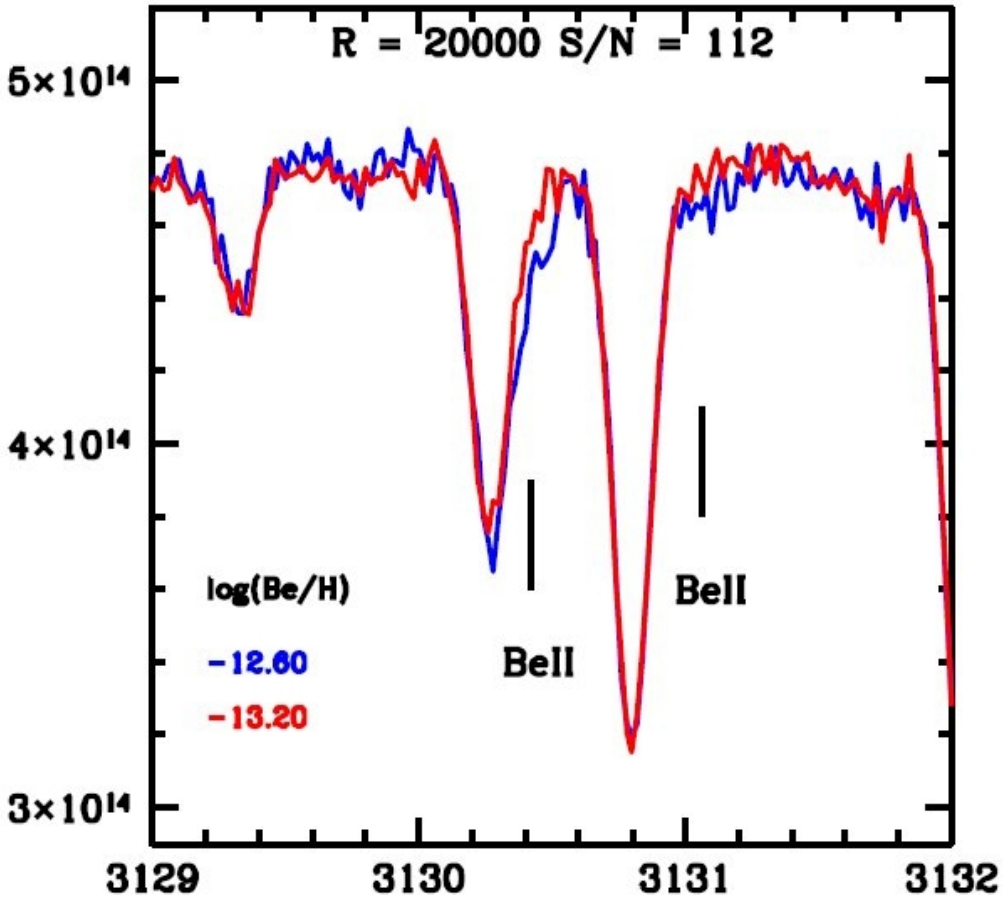




Globular Clusters and CUBES

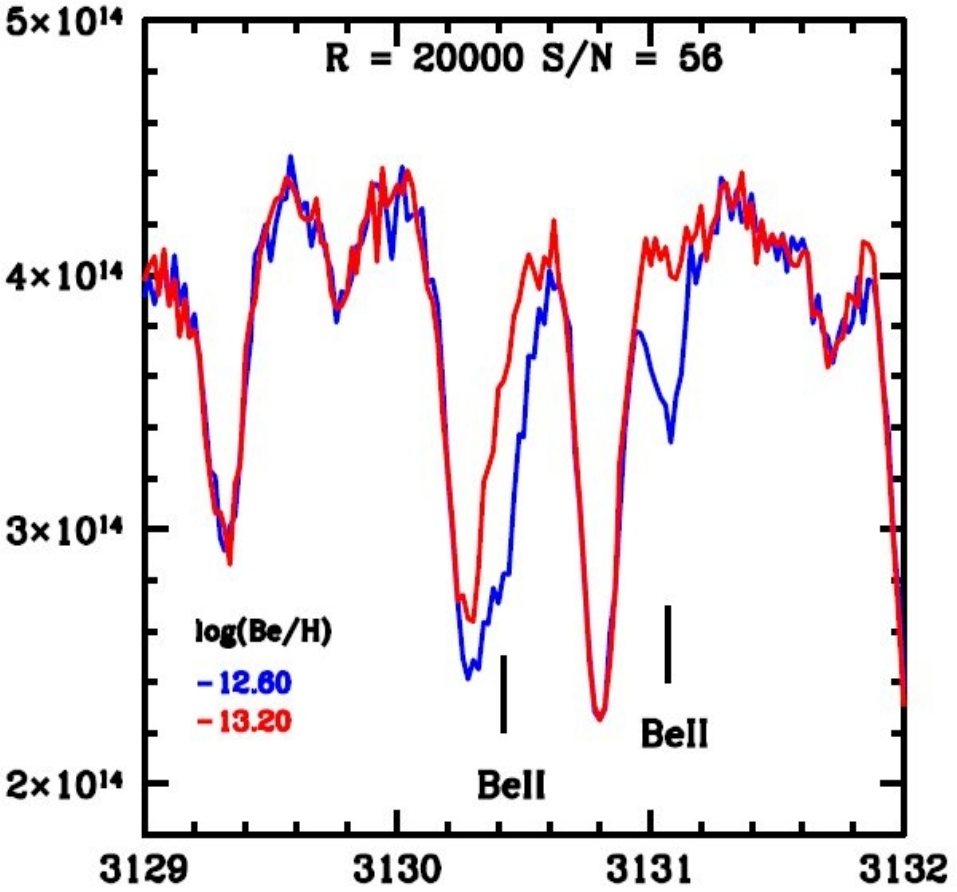
Turn-off stars in Omega Cen ([Fe/H] = -2.00)

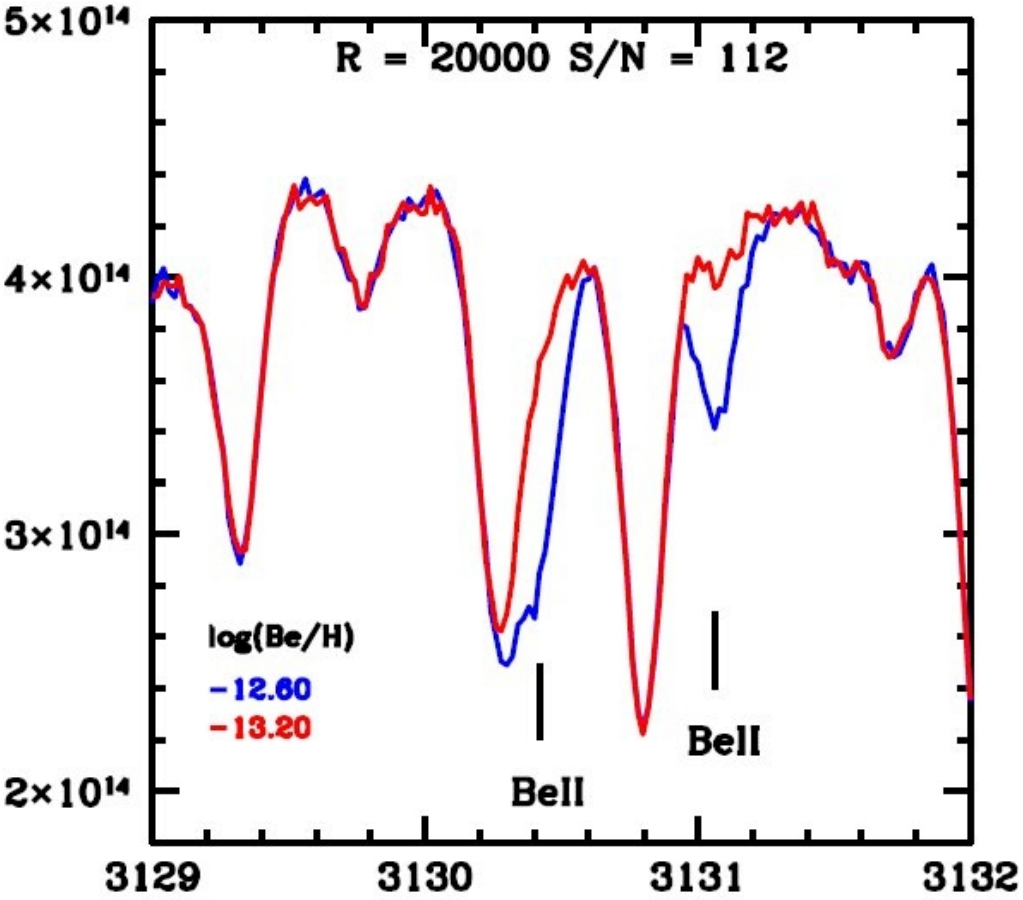




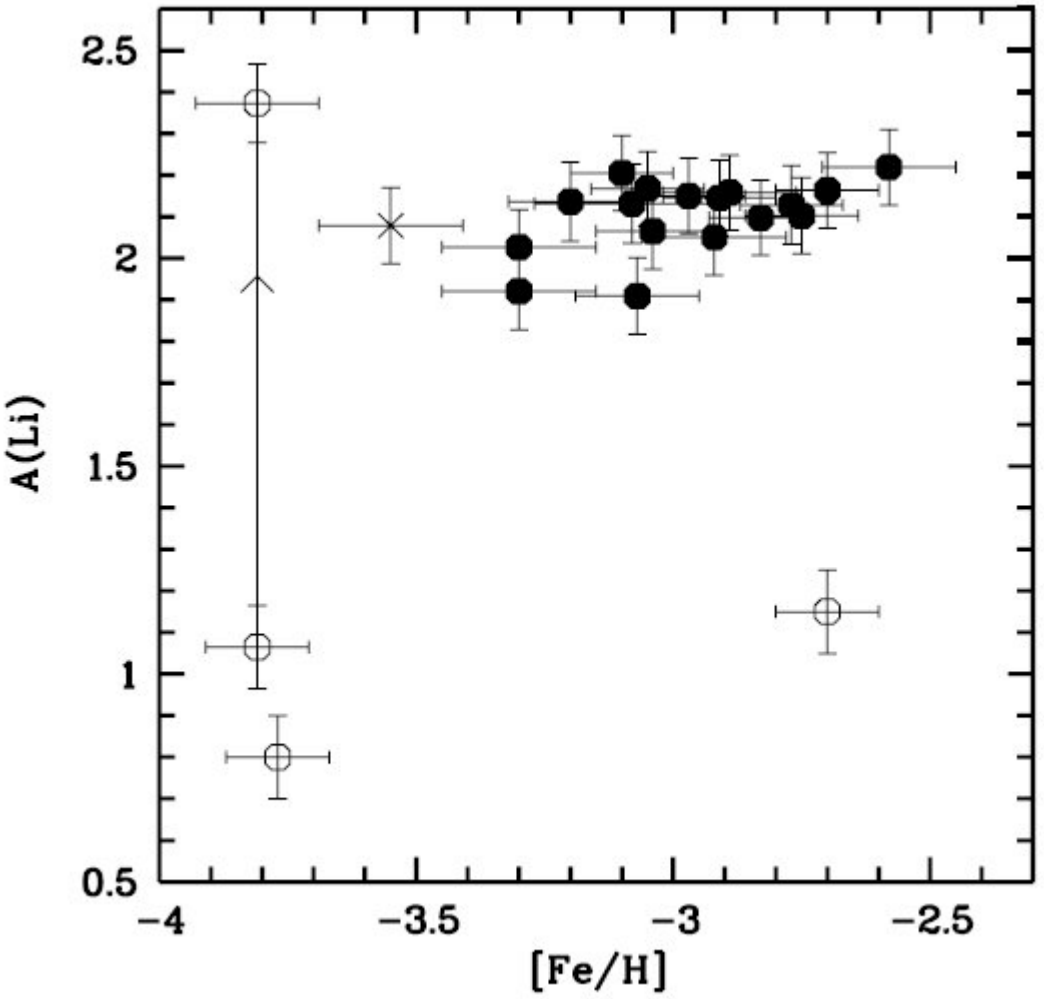
Globular Clusters and CUBES

Turn-off stars in Omega Cen ([Fe/H] = -1.10)





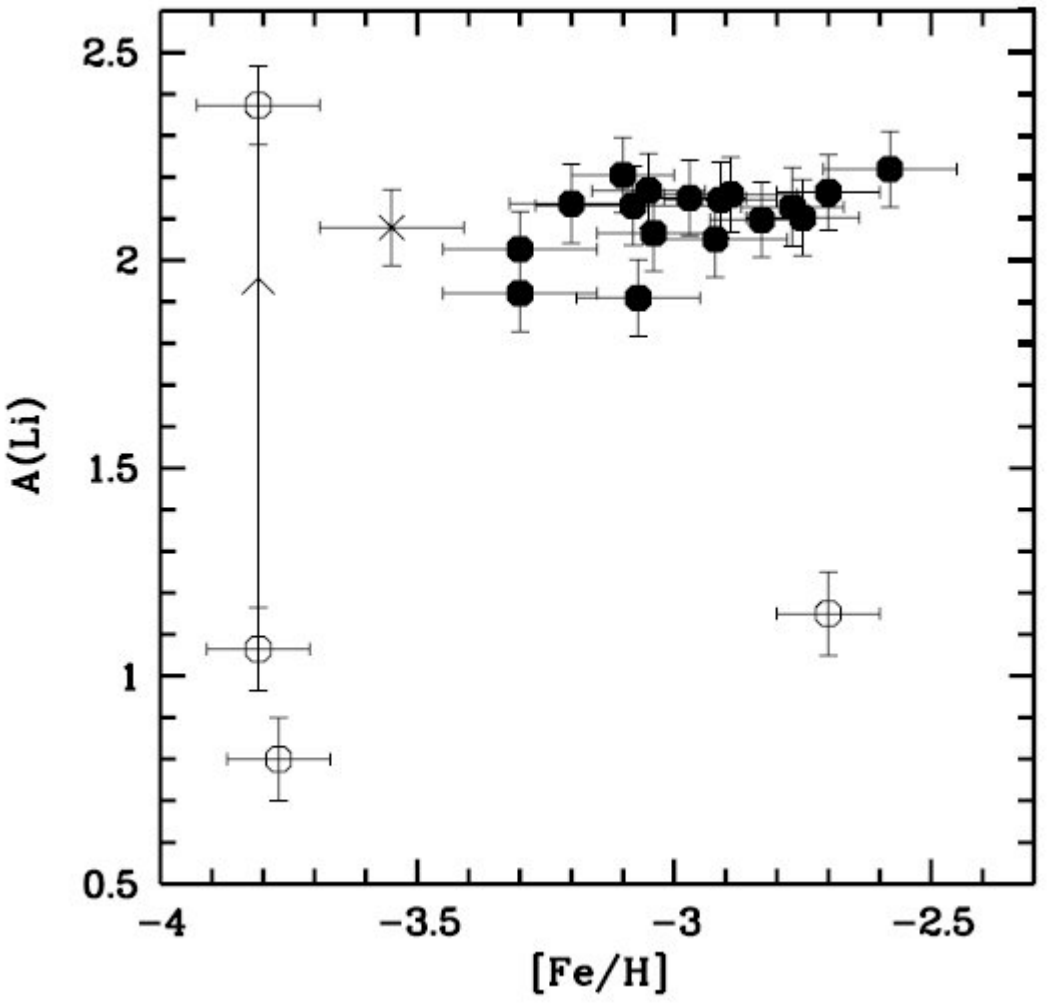
Metal-poor stars



(Bonifacio et al. 2007)

- Lithium: plateau of primordial origin
- And beryllium?

Metal-poor stars

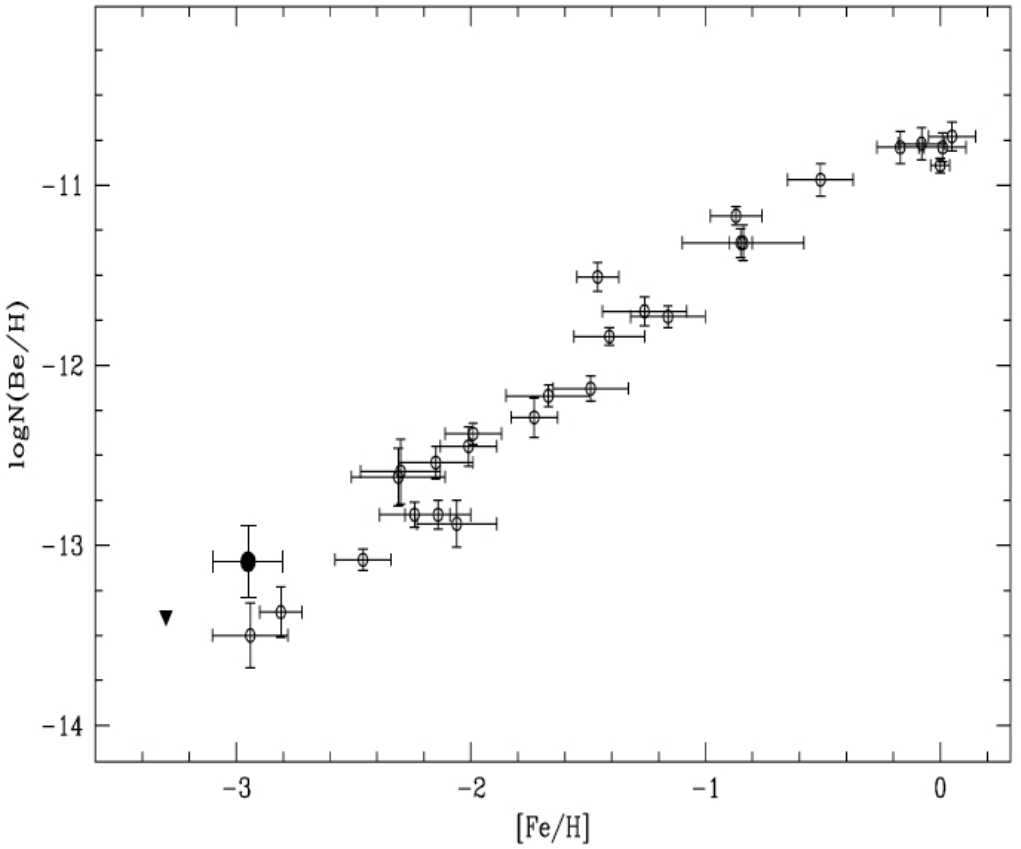


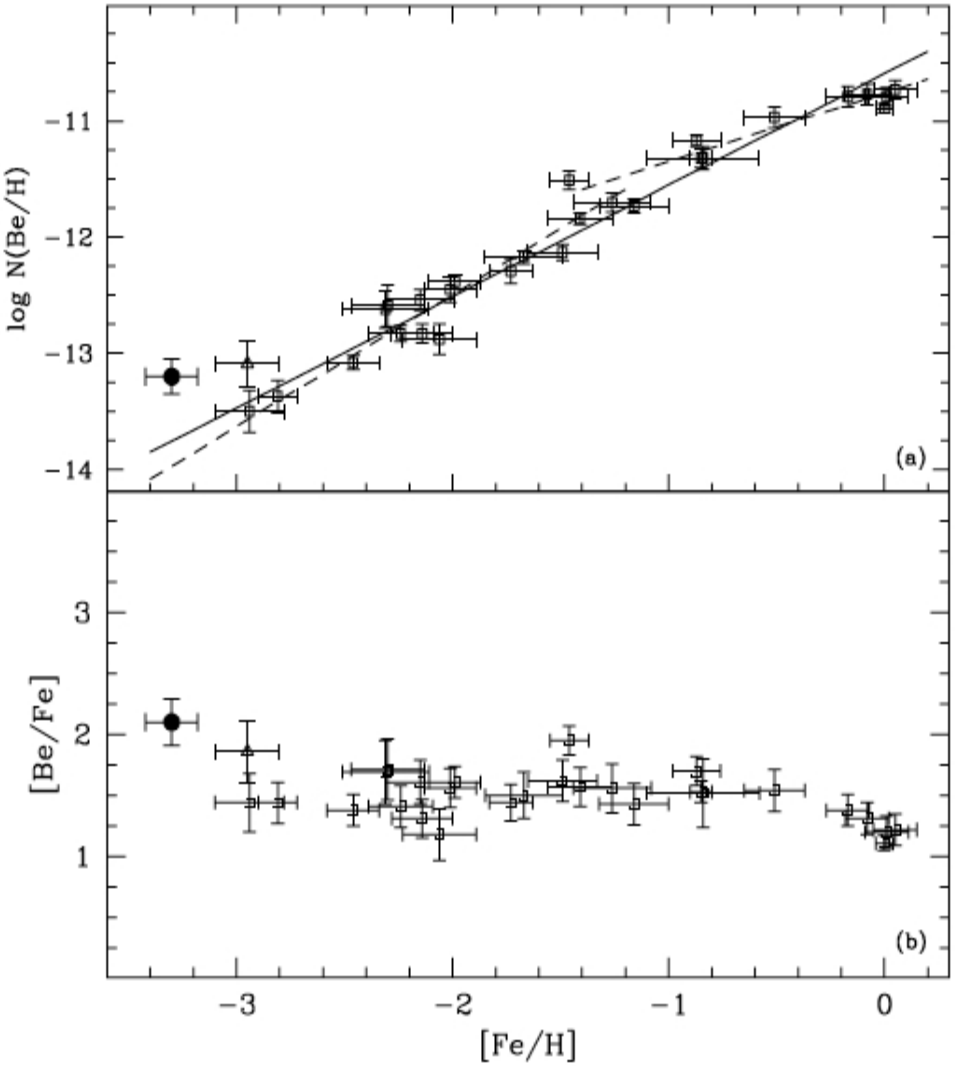
(Bonifacio et al. 2007)

- Lithium: plateau of primordial origin
- And beryllium?
- Not expected but...

1) Inhomogeneous primordial nucleosynthesis
2) Pre-Galactic cosmic rays
3) ...

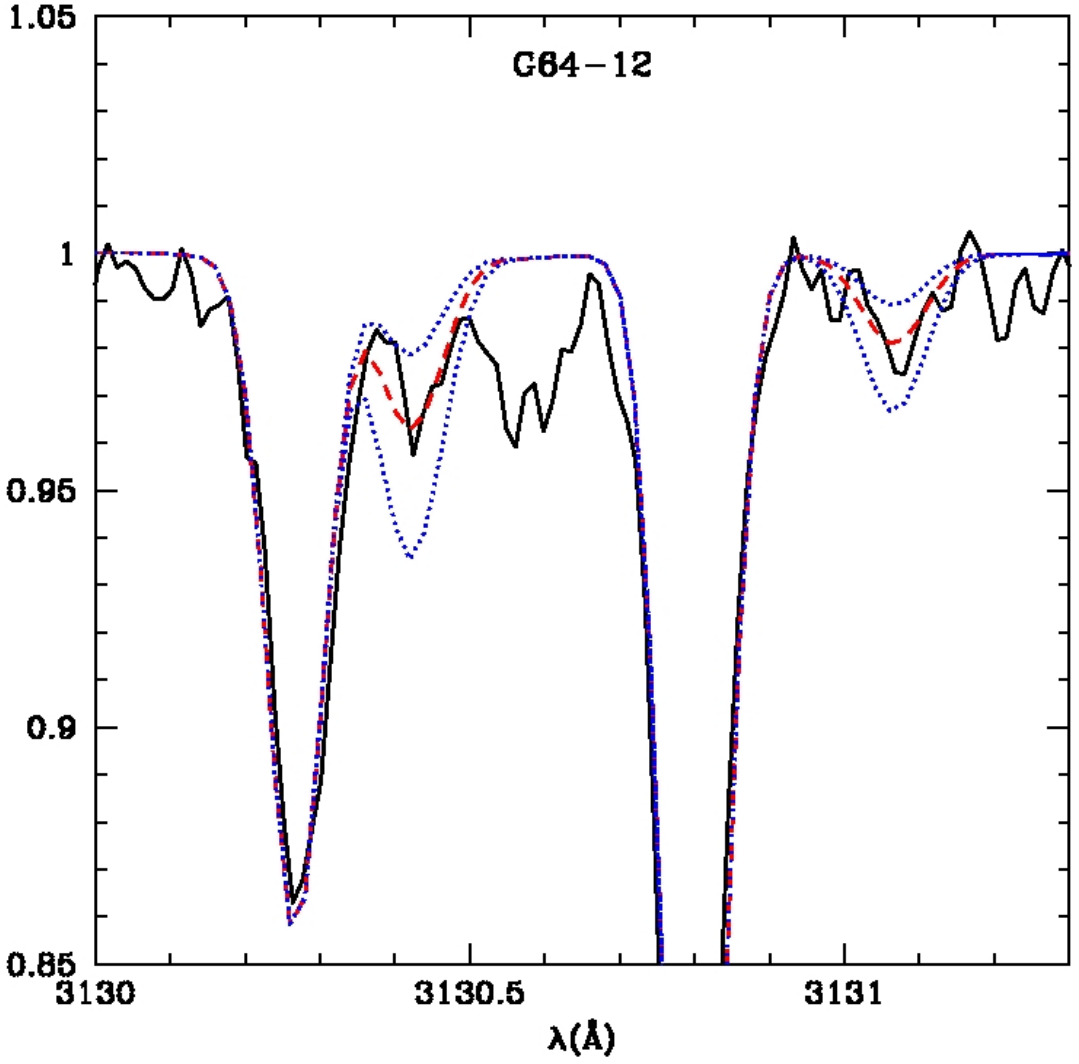
Metal-poor stars





(Primas et al. 2000a,b)

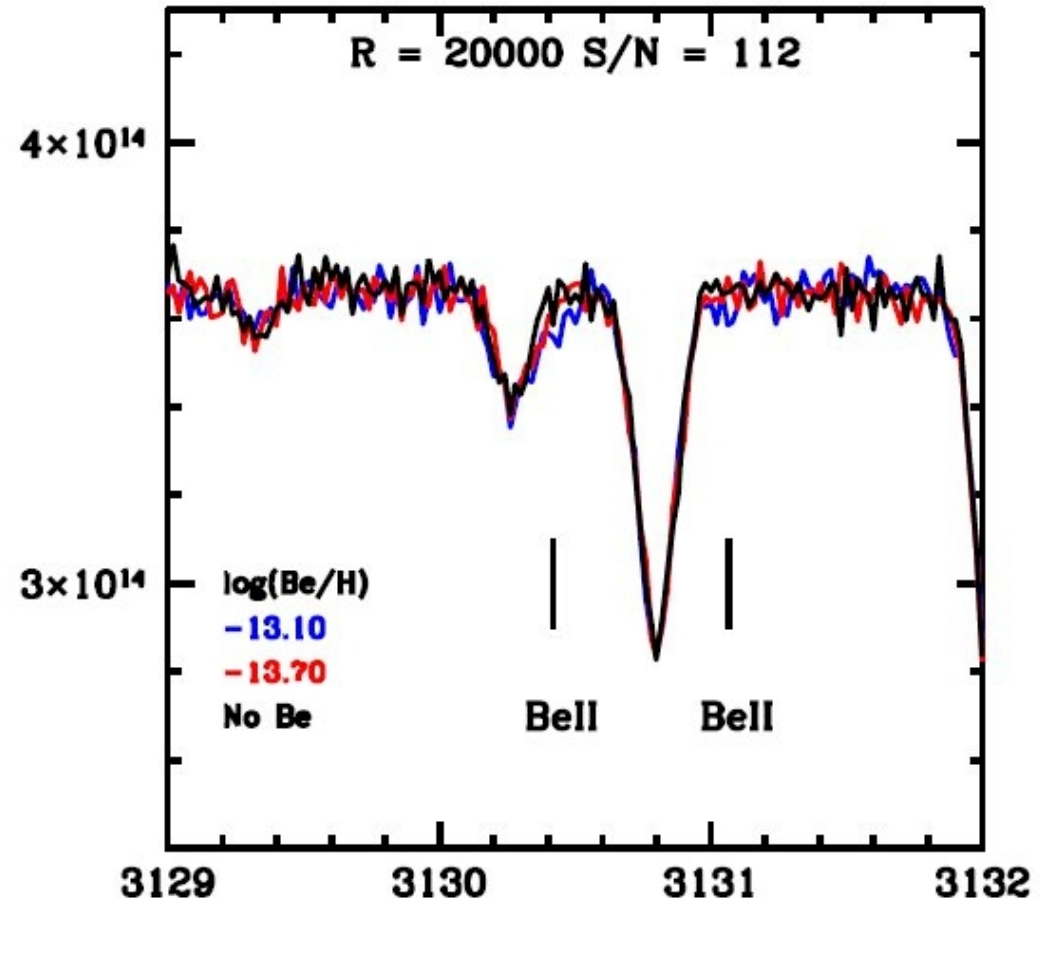
Metal-poor stars

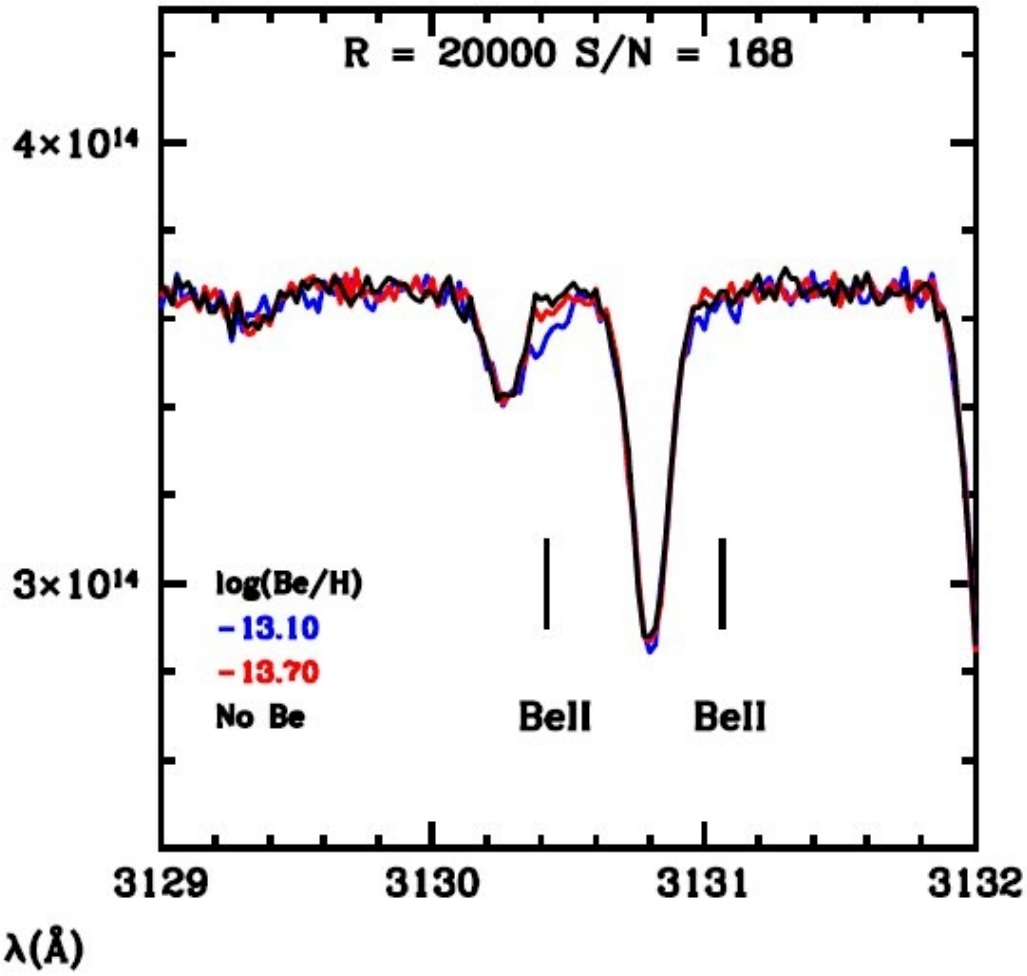


- G64-12
  [Fe/H] = -3.30
- Very weak Be lines

Metal-poor stars and CUBES

[Fe/H] = -3.00

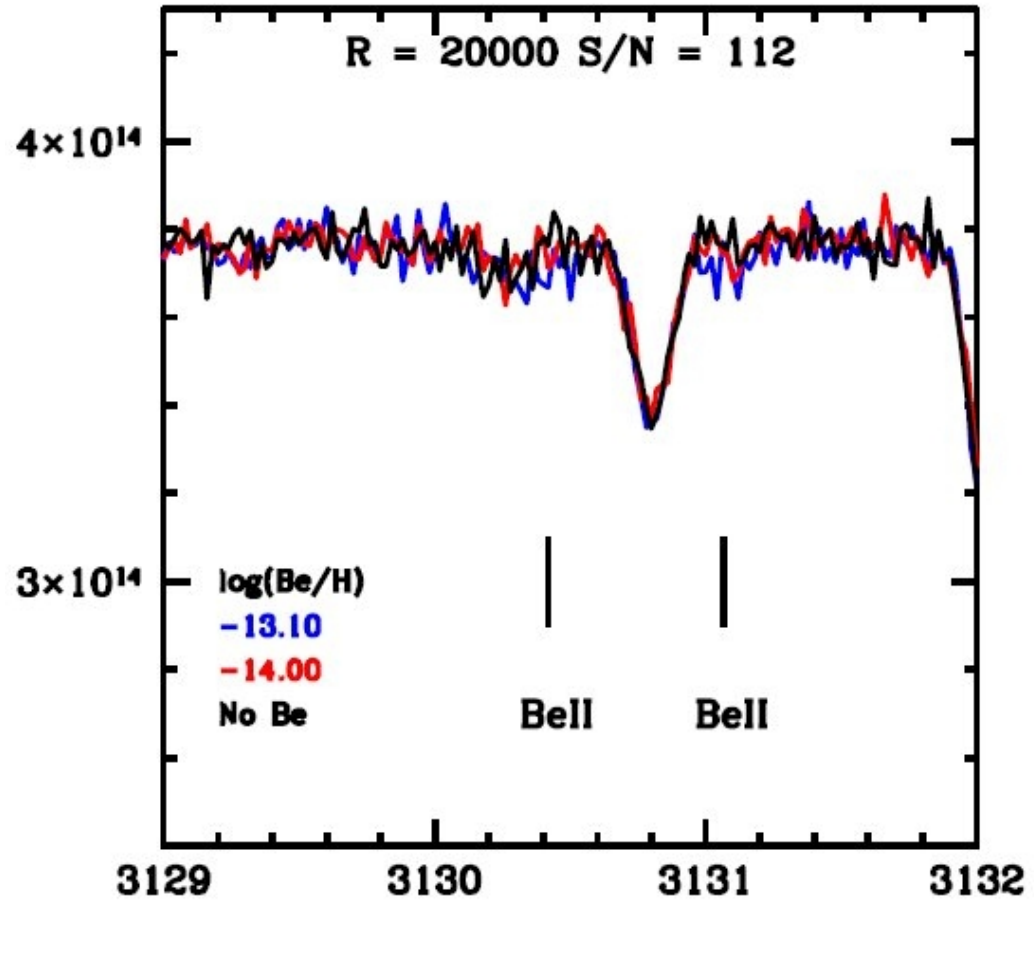


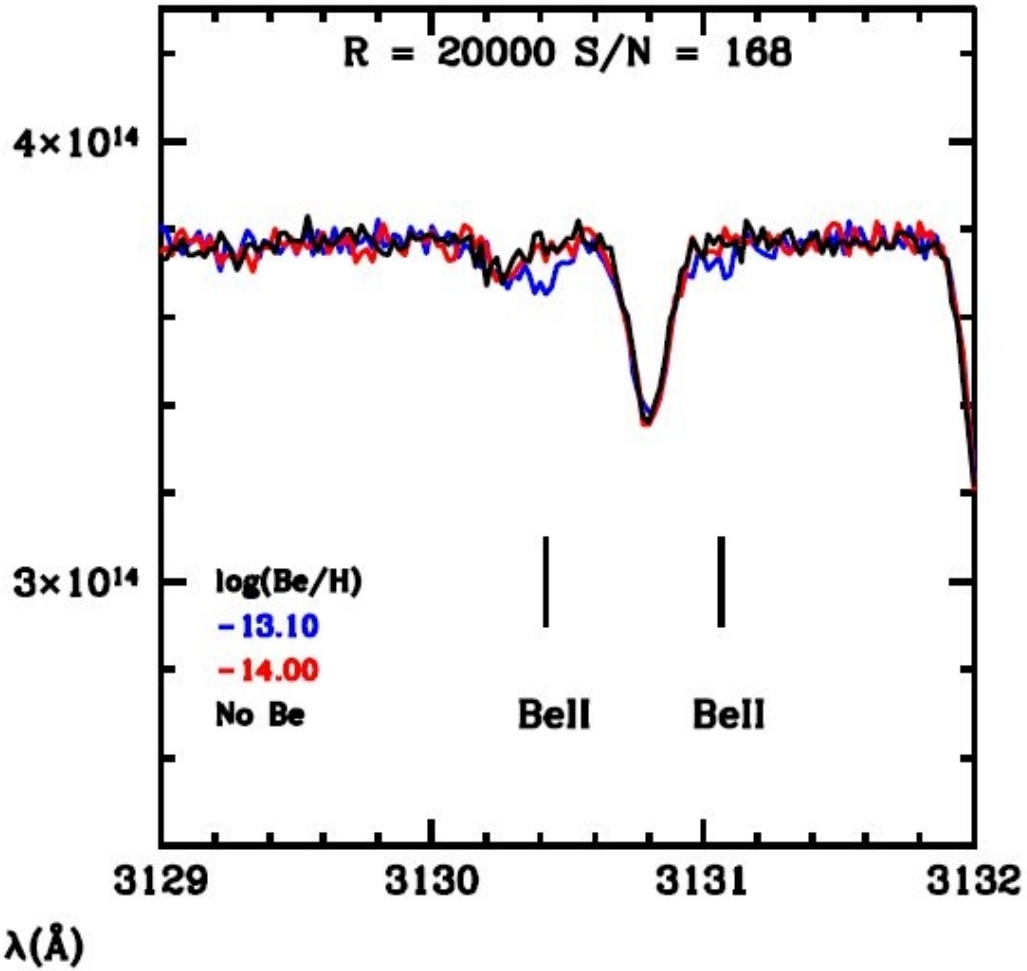


λ(Å)

Metal-poor stars and CUBES

[Fe/H] = -3.50





λ(Å)

SUMMARY

- Beryllium abundances have many applications
- But observations are time-consuming
- And the analysis is challenging

- ESO telescopes and instruments have made important contributions

- CUBES will be unique in its capabilities
- CUBES can bring the investigations a level further