Chemical tagging and the second r-process

NIC - Satellite workshop on r-process nucleosynthesis

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August 2012

Outline

- Stellar spectra and abundances
- The importance of atomic data
- What can we learn from stellar abundances
- Observational indications of a 2nd r-process
- A comparison to model yield predictions
- Conclusion

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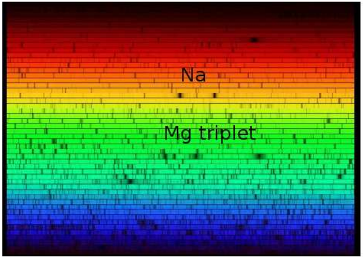
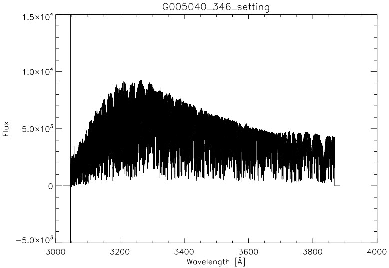
Stellar spectra and abundances



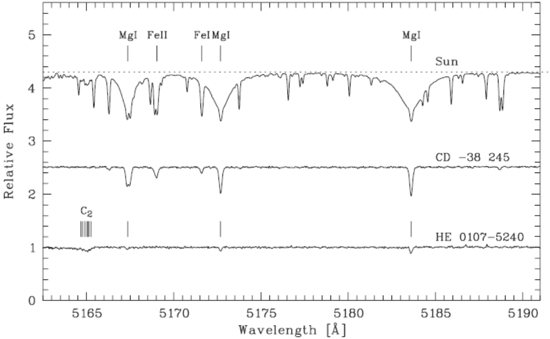


Stellar spectra and abundances

$$[\mathrm{Fe/H}] \equiv \log(N_{\mathrm{Fe}}/N_{\mathrm{H}})_* - \log(N_{\mathrm{Fe}}/N_{\mathrm{H}})_\odot \quad (1)$$

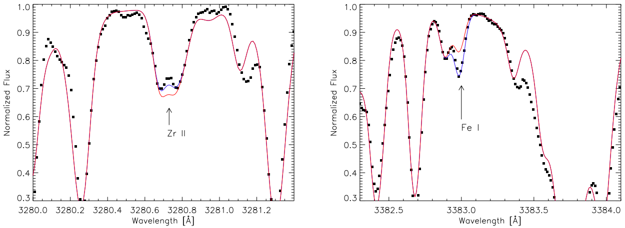
Top: Solar ([Fe/H] = 0) spectrum around the Mg triplet. Bottom: Star with [Fe/H]~ -5.

Christlieb et al, 2005



The importance of atomic data; Abundance - log gf relation

$$\log \mathrm{W} = \log(const) + \log(A) + \log(gf\lambda) - \theta\chi - \log(\kappa) \qquad (2)$$



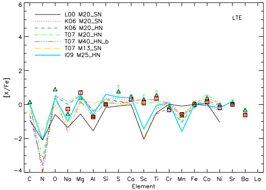
Hansen et al, 2012

Since the UV-region of the spectra is crowded we have to carry out spectral synthesis on line lists with accurate atomic data.

What can we learn from stellar abundances

- Observationally derived abundances for most MP RR lyrae
- The groups of elements trace various supernova (SN) features:
- α-elements serve as tracers of SN Mass (Kobayashi et al 06)
- The α/odd-Z elements provide information on the explosion energy, IMF and SN metallicity
- The amounts of Sc, Ti and Zn are linked to Y_e
- In-/complete Si-burning elements provide clues on the T_{peak}

Hansen et al, 2011a



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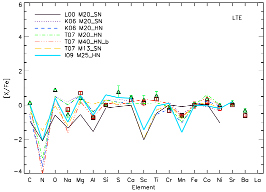
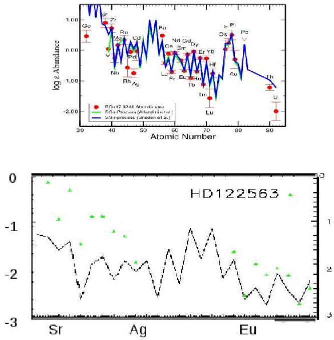
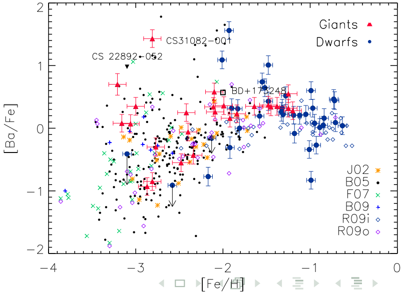


What can we learn from stellar abundances

- HD122563 - proto LEPP star
- Large star-to-star scatter for n-capture elements (e.g. Sr and Ba)

Cowan et al, 2011 and Hansen et al, 2012

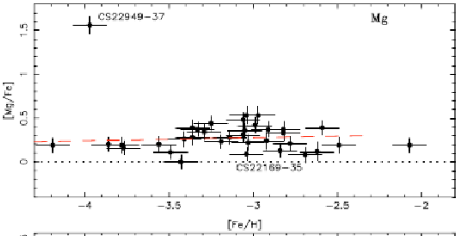


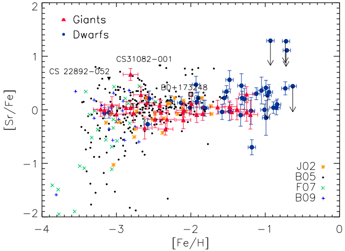


What can we learn from stellar abundances

- α - elements show a very low scatter
- Sr shows a very large scatter

Cayrel et al, 2004 and Hansen et al, 2012

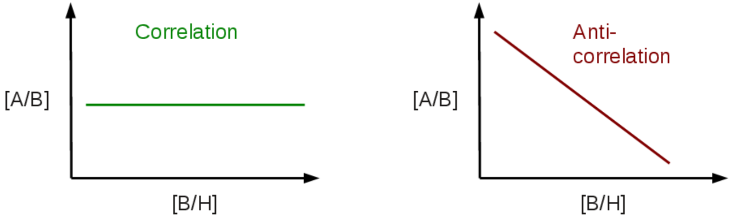




Correlation - Anticorrelation

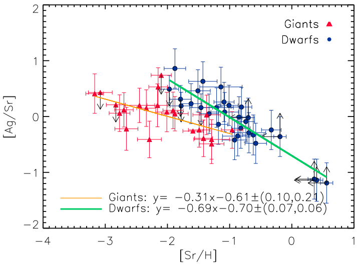
If two elements are created by the same process, they most likely grow in the same way (correlate).

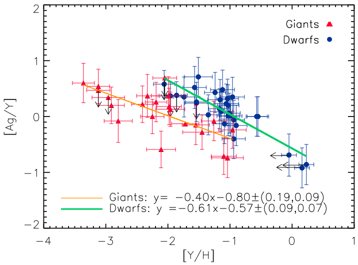
Elements (38$<Z<$ 50) are generally found to anti-correlate with Z $>$ 56 elements (Burris et al, 2000, Montes et al, 2007, Francois et al 2007)



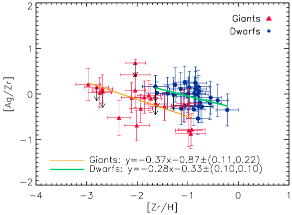
Weak s-process elements - Sr (85%) and Y (92%) Arlandini et al 1999

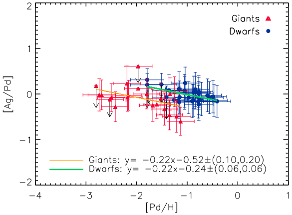
Hansen et al, 2012

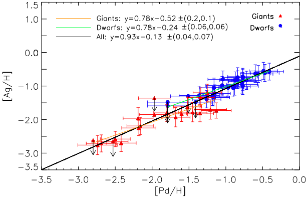




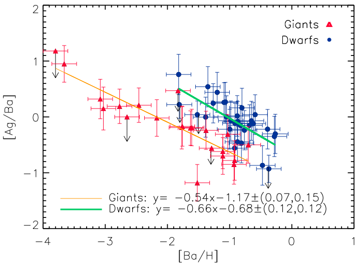
Weak s-process and weak r-process elements - Zr and Pd

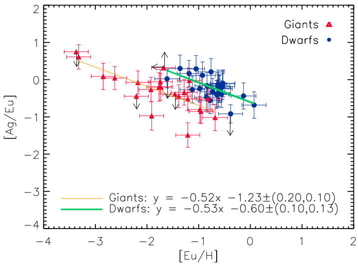






Main s-process and main r-process elements - Ba (81%) and Eu (94%)





Observational indications of a 2nd r-process

- Ag and Pd correlate - they are produced by the same process
- Ag does not correlate with the weak s-process elements; Sr and Y
- Ag does not correlate with Ba (main s-process at solar metallicity)
- Ag strongly anticorrelates with Eu (94% main r-process element; Arlandini et al 1999)
- Ag and Pd both created by the weak r-process
- How can we charactherize this 'weak' r-process

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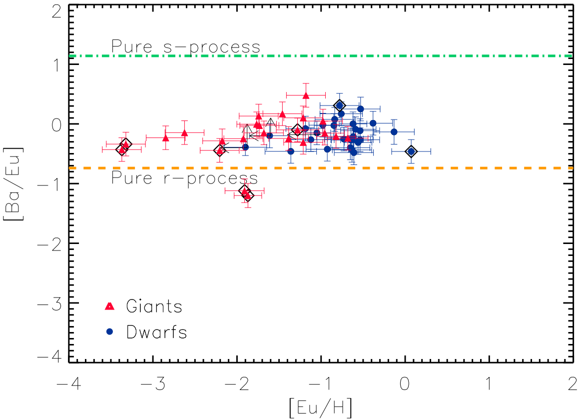
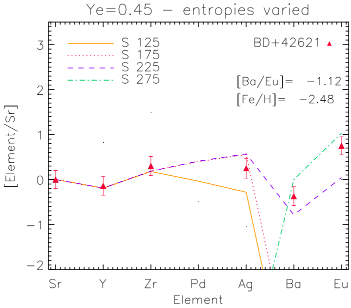
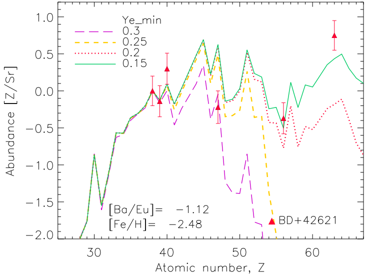
Pure r-process yields (Hansen et al, 2012)



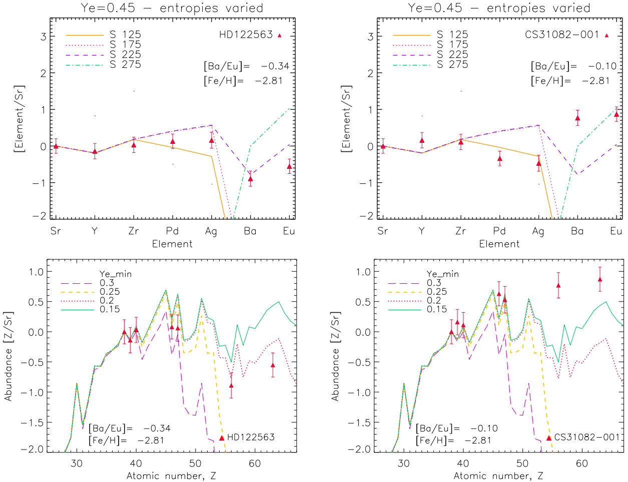
A comparison to model yield predictions (Hansen et al, 2012)



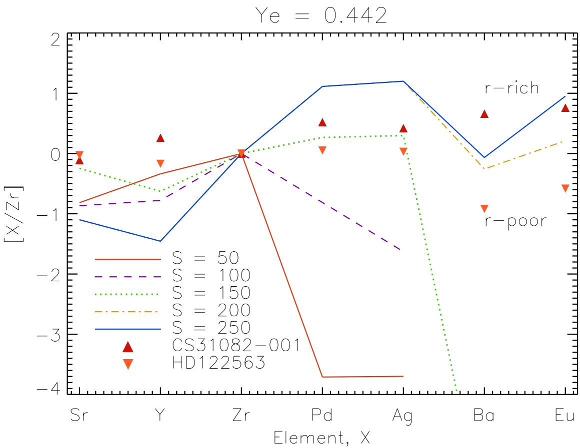


- High-Entropy Wind parametrized models with entropy (S), wind velocity (v) and Y_e as free parameters. Farouqi et al 2009,2010
- 2D models of Low-mass O-Mg-Ne core collapse SN based on selfconsistent explosion (no free parameters). Wanajo et al 2010,2011

r-poor vs r-rich stars: HD122563 & CS31082-001



The r-rich and r-poor stars show patters that require very different conditions from the explosion/environment



Conclusion

- It is important to have NLTE corrections for all abundances when comparing to SN yields, otherwise wrong conclusions on progenitor generation might be drawn (e.g. M and E off)
- A second/weak r-process is needed to produce/explain Ag and Pd
- This process is clearly different from the s-processes and the main r-process
- What is most 'physical'? A span of low Y_e 0.15-0.3 or high entropies S 125-275 kB/baryon...
- We need to understand the mixing processes, have 3D self consistent explosions and optimised yields, as well as 3D NLTE corrections for all abundances before we can constrain the early stellar generations and understand the r-processes

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A thanks to the organizers and thank you for listening

http://www.hexagonmetrology.com/eso-very-large-telescope-vlt-paranal_320.htm

Finally thanks to my collaborators: N. Christlieb, F. Primas, B. Leibundgut, K.-L. Kratz, S. Wanajo, H. Hartmann, O. Hallmann, M. Bergemann, B. Nordström, LSW, and SFB 881 for support.