The General Assembly of Galaxy Halos: Structure, Origin and Evolution
Proceedings IAU Symposium No. 317, 2015
A. Bragaglia, M. Arnaboldi, M. Rejkuba & D. Romano, eds.

doi:10.1017/S1743921315008352

r-Process Elements as Tracers of Enrichment Processes in the Early Halo

Johannes Andersen[1,2], Birgitta Nordström[1,2] and Terese T. Hansen[3]

[1]Dark Cosmology Centre, The Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, DK-2100 Copenhagen, Denmark
email: ja@nbi.ku.dk, birgitta@nbi.ku.dk

[2]Stellar Astrophysics Centre, Department of Physics and Astronomy, Aarhus University, DK-8000 Aarhus C, Denmark

[3]Landessternwarte, ZAH, Heidelberg University, Königstuhl 12, Heidelberg, D-69117, Germany
email: thansen@lsw.uni-heidelberg.de

Abstract. Significant minorities of extremely metal-poor (EMP) halo stars exhibit dramatic excesses of neutron capture elements. The standard scenario for their origin is mass transfer and dilution in binary systems, but requires them to *be* binaries. If not, these excesses must have been implanted in them from birth by processes that are not included in current models of SN II chemical enrichment. The binary population of such EMP subgroups is a test of this scenario.

Keywords. Galaxy: halo – Stars: chemically peculiar – binaries: spectroscopic – ISM: structure

1. Why might peculiar halo stars be interesting?

The bulk of extremely metal-poor (EMP) halo stars ([Fe/H] < -2.5) exhibit extremely well-defined abundance ratios between all elements up to Fe – see Frebel & Norris (2015). This is commonly taken to indicate that the early halo was enriched by a single class of sources and was promptly and well mixed, simplifying models of galaxy evolution. Yet, subgroups of EMP stars exist with dramatic excesses of neutron capture elements produced by the r and/or s processes and – even more importantly! – of carbon.

A solution, which was supported by literature data and has since been taken for granted, is that the excess elements were synthesized in an initially more massive binary companion, which has transferred the processed material to the surviving star by Roche-lobe overflow and/or a stellar wind. But *are* these stars *all* binaries? If not, the early halo was more complex – and more interesting! – than current models assume.

2. What we did

Our observing programme was simple in design: Systematic (∼monthly), precise radial velocity monitoring with the stable, bench mounted, fibre-fed échelle spectrograph FIES at the 2.5m Nordic Optical Telescope (NOT). Spectra of high resolution ($R \sim 45,000$) and low S/N ratio enable us to determine radial velocities with errors of ∼100 m s^{-1} over eight years and confidently discriminate between single stars and binaries.

3. What we found, and why it matters

Our results were simple, but surprising: The frequency (∼17±5%) and orbital properties of binaries enriched in r-process elements or in carbon but, unlike CEMP-s stars, not in s-process elements (CEMP-no stars) are *completely normal* (Fig. 1). In contrast, CEMP-s stars are ∼80% binaries; ∼20% remain single – see Hansen *et al.* (2015abc).

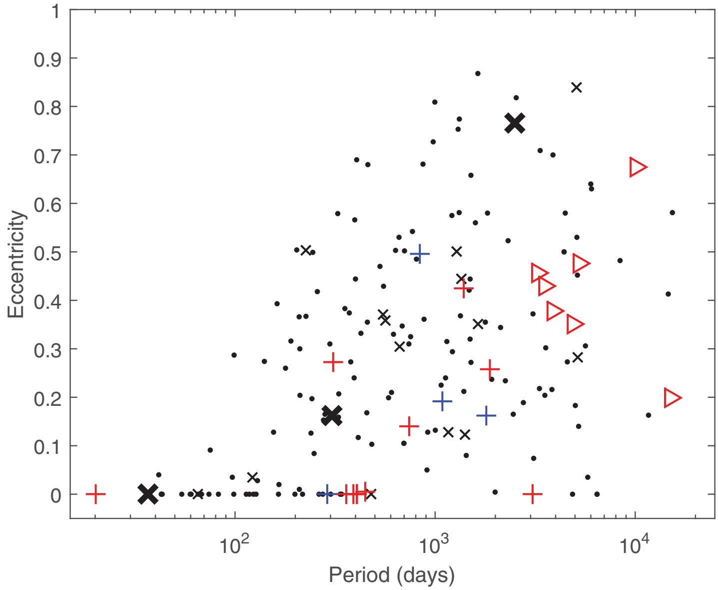

Figure 1. Period−eccentricity diagram for the binary systems observed in this project. Bold black crosses: Our three *r*-process enhanced binaries; red and blue crosses: CEMP-*s* binaries with and without(CEMP-no) *s*-process element enhancements, respectively (systems with $P > 3,000$ days are shown as right-pointing triangles since their true periods may be even longer). Black dots and small crosses: Comparison samples of giant binaries in Population I clusters: Mermilliod *et al.* (2007), Mathieu *et al.* (1990) and in Population II: Carney *et al.* (2003).

So the binary mass-transfer scenario can account for one class of peculiar halo stars, but by far not for all: the excess elements in the single stars must have been produced elsewhere and transported across interstellar distances in the ISM to pollute some, but not all of the natal clouds of long-lived EMP stars. For details, see Hansen *et al.* (2015abc). Yet another complexity in the life of galaxy modellers!

Acknowledgements:
This paper is based on observations made with the Nordic Optical Telescope, operated by the Nordic Optical Telescope Scientific Association at the Observatorio del Roque de los Muchachos, La Palma, Spain, of the Instituto de Astrofísica de Canarias. We thank many NOT staff members and students for readily obtaining most of the observations for us in service mode. We also thank our co-authors on the full papers on this work.
JA and BN gratefully acknowledge financial support from the Carlsberg Foundation and the Danish Natural Science Research Council, and TTH was supported by Sonderforschungsbereich SFB 881 "The Milky Way System" (subproject A4) of the German Research Foundation (DFG).

References

Carney, B. W., Latham, D. W., Stefanik, R. P., *et al.*, 2003, *AJ*, 125, 293
Frebel, A. & Norris, J. E., 2015, *ARAA*, 53, 631
Hansen, T. T., Andersen, J., Nordström, B., *et al.* 2015abc, *A&A*, in press
Mathieu, R. D., Latham, D. W., & Griffin, R. F. 1990, *AJ*, 100, 1899
Mermilliod, J.-C., Andersen, J., Latham, D. W., & Mayor, M., 2007, *A&A*, 473, 829

https://doi.org/10.1017/S1743921315008352 Published online by Cambridge University Press