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# Chemical Abundances in the Carina dwarf spheroidal galaxy


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***Overview:***
Carina is the only dwarf spheroidal (dSph) galaxy known to have experienced episodic star formation (SF), interrupted by long quiescent periods (e.g., Smecker-Hane et al. 1994). Low resolution spectroscopy has revealed a mean metallicity of -1.7 dex with a wide range from ca. -3 to 0 dex (Koch et al. 2006). Thus there is strong evidence of a considerable enrichment over most of Carina’s evolutionary lifetime from 12 Gyr to a few Gyr ago. However, in order to impose stronger constraints on the modes of SF in the dSphs, individual chemical element ratios are a necessity.
Here we present chemical abundance ratios of Fe, O and Ca in 21 in red giants obtained from high-resolution spectroscopy that we carried out using (1) the UVES spectrograph at the ESO/VLT and (2) the Multi-Object Echelle (MOE) spectrograph at the Magellan/Baade 6.5m Telescope. For the analysis of further heavy elements in Carina see Koch (2006). While our UVES stars were purely selected from colour-magnitude criteria, the MOE targets were drawn from the low-resolution spectroscopic set of Koch et al. (2006), such as to pre-select a broad metallicity range, desirably covering the full extent of Carina’s SF history.

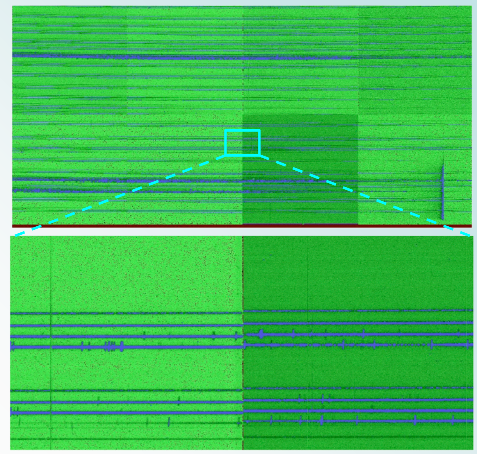
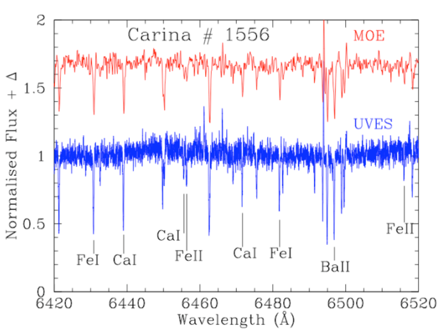


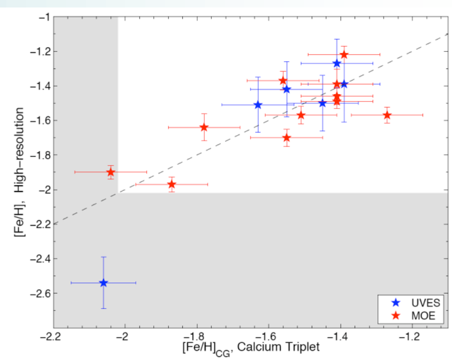
***Fig.1:*** Images of the Carina slit spectra across the array of MOE’s eight CCDs .




| Instrument | UVES (ESO/VLT) | MOE (Magellan/Baade) |
|---|---|---|
| Number of targets | 10 | 20 [11 reduced] |
| Spectral range | 4800 - 6800 Å | 4700 - 7500 Å |
| Spectral resolution | 40000 | 16000 - 20000 |
| Average S/N | 20 | 30 |

***Fig.2:*** Sample spectra of the same star, observed with both UVES and MOE.

***Fig. 3: Assessing the calcium triplet (CaT) metallicity scale:***
For six of our UVES targets CaT based metallicities were measured by Koch et al. (2006). Our MOE stars were all selected from the CaT list of Koch et al. (2006). There is generally good agreement between the high-resolution iron abundances determined in this work and the low-resolution CaT metallicites. However, the absence of a zero-point shift in Figure 3 is a little surprising, because the CaT calibration was based on Galactic globular clusters (GGC), that possess [α/Fe] ratios of +0.4 dex, whereas our Carina stars have rather lower [Ca/Fe] ratios of typically 0.2 dex (see Fig. 4). The gray-shaded area is the region in metallicity that was ***not*** covered by the original GGC calibration sample of Rutledge et al. (1997). Hence, all measurements in this regime rely on an extrapolation of the traditional calibrations and it is not surprising that our observed star with the lowest metallicity shows a significant discrepancy between both values.



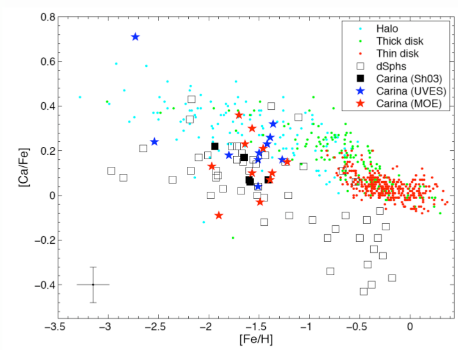




***Fig. 4: Ca abundances in Carina:***
This diagram confirms that dSph stars are generally depleted in Ca with respect to to *all* Galactic components, which is a trend seen in all of the α-elements and directly reflects the slow chemical evolution of the dSph galaxies (see also Unavane et al. 1996; Shetrone et al. 2003 [Sh03]; Venn et al. 2004). In this context, Carina is no exception, and the majority of its stars fall below the trends delineated by the Galactic halo and thick and thin disk. Some of our targets, however, show slightly enhanced [Ca/Fe], which reaches halo-like values as high as +0.4. Such an overlap in the halo plateau is consistent with an invariant massive star IMF. Note that the most metal poor star is even more considerably enhanced in Ca. Overall, our findings indicate a large star-to-star scatter.

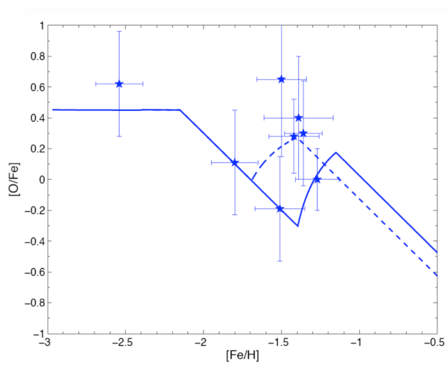



***Fig. 5: Carina’s Chemical Evolution :***
Our derived [O/Fe] abundance ratios for the UVES targets are shown with two models from the predictions of Gilmore & Wyse (1991). These models consist of two star formation bursts separated by an extended hiatus. These models were originally computed for LMC/SMC data and thus were shifted by 0.4 in [Fe/H] such as to give the best representation of our observations. The two different lines were computed for two different metallicities at which the second star burst sets in. This comparison suggests the this SF burst in Carina occurred at a mean metallicity of about -1.5 (see also Shetrone et al. 2003), with potential intrinsic variations that are consistent with an inhomogeneous SF and enrichment. However, in the light of the measurement uncertainties this comparison has to be taken with caution and we refrain from a detailed quantification of Carina’s SF history and model parameters at this stage.

***Further reading:***

Koch et al. 2006, AJ, 131, 895
**Koch, A. 2006, Ph.D. Thesis, University of Basel, http://pages.unibas.ch/diss/2006/DissB_7665.htm**
Gilmore & Wyse, ApJ, 367, L55
Shetrone et al. 2003, AJ, 125, 684
Smecker-Hane et al. 1994, AJ, 108, 507
Rutledge et al. 1997, PASP, 109, 907
Unavane et al. 1996, MNRAS, 278, 727
Venn et al. 2004, AJ, 128, 1177