The ARAUCARIA Project –
First Observations of Blue Supergiants in NGC 3109

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NGC 3109 is an irregular galaxy at the edge of the Local Group at a distance of 1.3 Mpc. Here we present new VLT observations of its young, massive star population, which have allowed us to probe stellar abundances and kinematics for the first time. The mean oxygen abundance obtained from early B-type supergiants confirms suggestions that NGC 3109 is very metal poor. In this context we advocate studies of the stellar population of NGC 3109 as a compelling target for future Extremely Large Telescopes (ELTs).

The ARAUCARIA Project is an ESO Large Programme using FORS2 on the VLT. Its principal motivation is to provide improved distances to galaxies in the Local and Sculptor Groups, via the period-luminosity relationship of Cepheid variables (Gieren et al. 2005). A secondary component of the project is to characterise tens of blue supergiants (typically B- and A-type stars) in each of the target galaxies. Blue supergiants are the most visually luminous 'normal' stars, thereby enabling direct studies of stellar populations in galaxies that are otherwise unreachable with 8-m telescopes. From comparisons with theoretical spectra, we can investigate physical parameters such as temperatures and chemical abundances of our targets, obtaining estimates of the metallicity of the host systems. Moreover, blue supergiants have also been advanced as an alternative method of distance determination via the flux-weighted gravity luminosity relationship (Kudritzki et al. 2003).

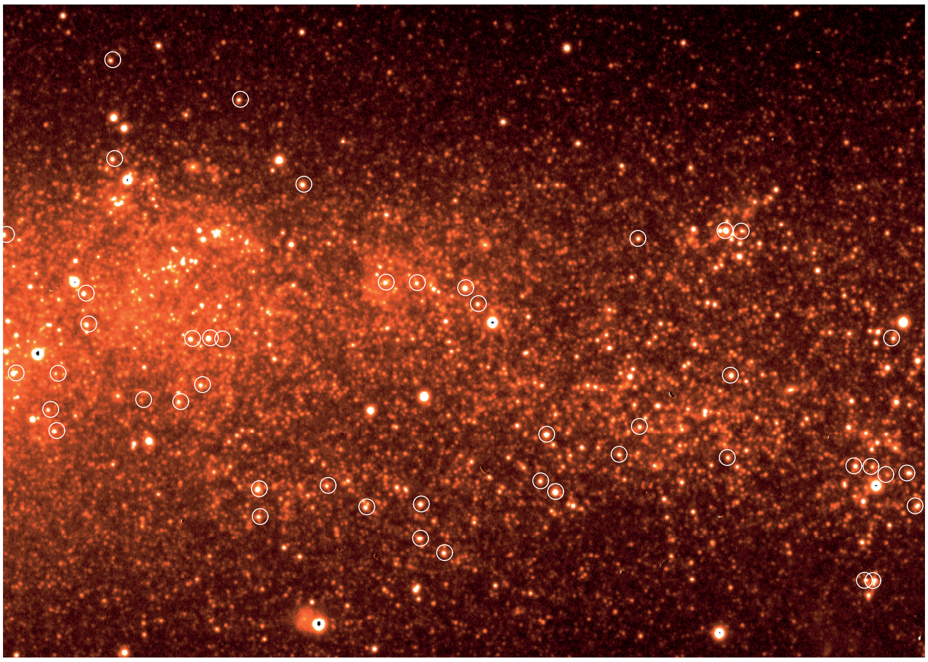

Figure 1: Part of the *V*-band FORS pre-image of our most western field, with the targets encircled. NGC 3109 is approximately edge-on and the FORS targets are well sampled along both the major and minor axes.

NGC 3109 is a large Magellanic Irregular at 1.3 Mpc, which puts it at the outer edge of the Local Group. Using FORS2 in the configurable MOS (multi-object spectroscopy) mode, we have observed 91 stars in NGC 3109. These were observed in 4 MOS configurations, using the 600 B grism (giving a common wavelength coverage of λ3900 to λ4750 Å). The cumulative exposure time for each field was roughly 3 hours. Part of our most western field is shown in the FORS pre-image in Figure 1, with our targets encircled. From published photometry it has been suggested that red giants in NGC 3109 have metal abundances that are similar to those found in stars in the Small Magellanic Cloud (SMC), i.e. very metal poor when compared to the solar neighbourhood. With this in mind, we classified the FORS spectra using criteria that have already tackled the issue of low metallicity (e.g. Evans et al. 2004). Our sample is primarily composed of late-O, B and A spectral types – this is the first spectral exploration of this galaxy. As an aside, we note that the first large-scale CCD survey of NGC 3109 was reported in this publication by Bresolin et al. (1990) – the acquisition of high-quality spectroscopy in this galaxy some 16 years later illustrates the considerable advancement in studies of extragalactic stellar populations over that period.

Example spectra are shown in Figure 2. Of our 91 targets, 12 are late O-type stars, ranging from O8 to O9.5 – such high-quality observations of resolved O-type stars (note the He II emission 'bump' at λ4686 Å in the spectrum of star #33) beyond 1 Mpc are really quite remarkable.

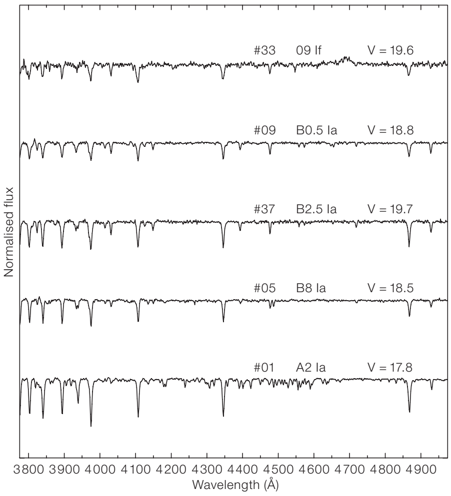

Figure 2: FORS spectra of five of our targets in NGC 3109. The quality of the data is particularly impressive when one remembers that the stars are at distances of over 1 Mpc.

However, in terms of quantitative analysis, the early B-type supergiants in our sample are of more immediate interest – these stars have a wide variety of strong metallic lines in their absorption spectra, providing an excellent tool for investigating chemical abundances of young stellar populations.

We have analysed a subset of eight of our early B-type spectra using the FASTWIND model atmosphere code (Puls et al. 2005). From comparisons with theoretical spectra we can obtain physical parameters such as temperatures, gravities, and, of most interest in a broader context, chemical abundances. An example FASTWIND model matched to one of the observed spectra is shown in Figure 3. The mean oxygen abundance in our eight stars is found to be log(O/H) + 12 = 7.76 ± 0.07, in excellent agreement with results from H II regions. This is only ~ 12 % of the oxygen abundance found in the solar neighbourhood, and is lower than the oxygen abundances found in the SMC (cf. log(O/H) + 12 = 8.13, Trundle and Lennon, 2005). We also obtain upper limits to the magnesium and silicon abundances, which are comparable to those found for stars in the SMC – the exact abundance of the alpha-elements will require higher-resolution spectroscopy, but it is clear that stars in NGC 3109 have metal abundances that are very deficient when compared to the solar neighbourhood, and likely even lower than in the SMC.

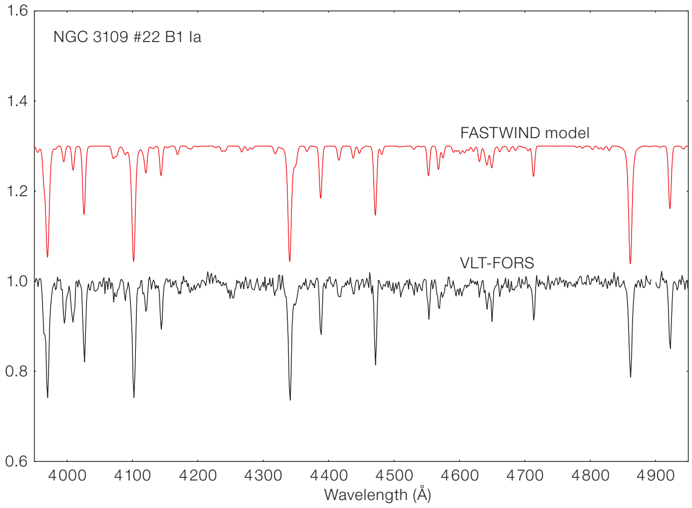

Figure 3: FORS spectrum (black line) of star #22, classified as B1 Ia. A FASTWIND model spectrum (T_{eff} = 22 000 K, log$g$ = 2.60) is shown above in red, smoothed to the same resolution as the FORS data.

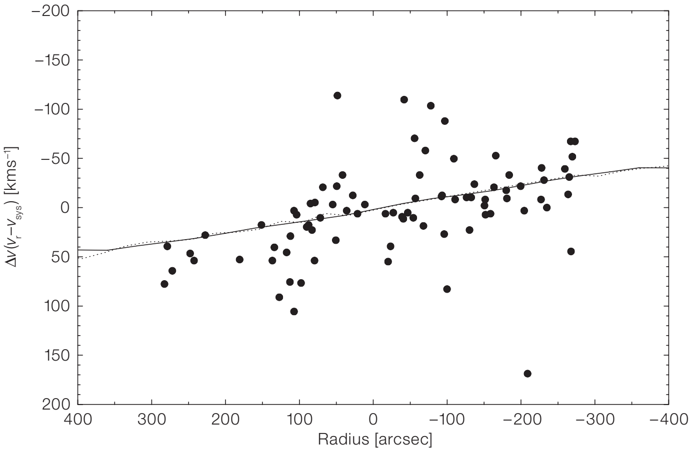

Figure 4: Differential radial velocities as a function of radius along the major axis of NGC 3109 – typical uncertainties are of order ± 20 km/s. Also shown are rotation curves from H I (solid line) and Hα (dotted line).

We have also used our FORS spectra to investigate the stellar rotation curve of NGC 3109. H I observations suggest a dominant dark-matter halo (Jobin and Carignan 1990), that cosmological N-body cold dark matter simulations have struggled to reproduce (Navarro et al. 1996). The spectral resolution from FORS (R ~ 1,000) is somewhat limiting for studies of stellar kinematics, but from simple measurements of line-centres of hydrogen and helium lines, we estimated radial velocities for the majority (84) of our stars. The mean 1-sigma (internal) uncertainty is of order 20 km/s. Figure 4 shows differential radial velocities for each of our stars, compared with published results from H I radio maps and Hα imaging (Jobin and Carignan 1990, Blais-Ouellette et al. 2001). As one might expect, the velocities of the young population largely trace those of the gas, with a fair amount of scatter. Further observations of this sort would be of value to ascertain whether the stellar results are revealing genuine sub-structures in the disc, or whether we are simply limited by the small sample/spectral resolution.

Plans for the next generation of large ground-based telescopes, the so-called Extremely Large Telescopes (ELTs), are now gaining momentum. In this context we suggest NGC 3109 as an exciting opportunity to study many stages of stellar evolution in a very metal poor environment. A large primary aperture would enable high-resolution spectroscopy of the young, massive population, and of stars on the asymptotic giant branch. Meanwhile, lower-resolution spectroscopy could trace the kinematics of the non-supergiant population (e.g. via the Calcium Triplet), probing the outer structure of this dark-matter dominated dwarf and providing crucial input for cosmological simulations.

References

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