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Δa Photometric Survey of the Small Magellanic Cloud

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Abstract. The narrow-band Δa photometric system measures the flux depression at λ 5200 Å by comparing the flux at the band centre to adjacent regions. It has been shown that virtually all peculiar stars with magnetic fields (mCPs) have significant positive Δa values (of up to +100 mmag), whereas Be/Ae/B[e] and metal weak stars (including lambda Bootis types) exhibit significant negative values of Δa. By using this photometric system we are therefore able to detect chemically peculiar (CP), emission types and metal-weak stars in an efficient way. The poster presented the first results of our survey of the Small Magellanic Cloud. In the selected field we found only 0.5 % of *bona fide* CP stars against 15 % in our Galaxy.

Keywords. Stars: chemically peculiar, stars: emission-line, Be, galaxies: Small Magellanic Cloud, techniques: photometric: Δa

1. Introduction

Three-filter (g_1, g_2, y) narrow-band Δa photometry was designed to detect objects which exhibit a flux depression at λ 5200 Å, namely the chemically peculiar stars of the upper main sequence (Maitzen 1976). However, it subsequently turned out that several other objects of all spectral types and luminosity classes also have peculiar features in that region. The g_2 filter (FWHM ∼100 Å) measures the flux at λ 5200 Å by comparing the flux at the band centre to that at any adjacent region. Paunzen *et al.* (2005) showed that virtually all peculiar stars with magnetic fields have significant positive Δa values of up to +100 mmag, whereas Be/Ae and metal-weak stars exhibit significantly negative ones.

The CP stars (covering the range B0–F4) are excellent astrophysical laboratories that enable the testing of current theories on stellar formation and evolution in the presence of a magnetic field, element diffusion, meridional circulation and stratification. The hot end is defined by the onset of strong stellar winds, the cool end by increasingly strong convection in the atmosphere. Several subgroups exhibit inhomogeneous surface distributions of elements, which lead to spectroscopic and photometric variations within the rotation period (Paunzen *et al.* 2015). The rotation can thus be measured directly from photometric time series – a unique opportunity among stars of these spectral types.

Since the 1970s CP and other non-standard stars in the Galactic field and in open clusters have been targets of photoelectric observations, and more latterly of CCD Δa photometry, leading to numerous publications. Observations have since been extended to globular clusters and to the Large Magellanic Cloud to search for all types of non-standard objects (Paunzen *et al.* 2014).

This poster outlined a comprehensive Δa photometric survey of the Small Magellanic Cloud (SMC), and presented first results.

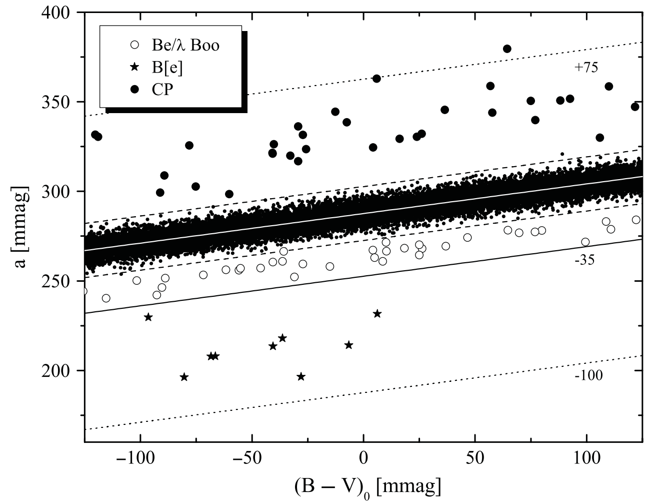

Figure 1. One $30' \times 30'$ field of the SMC observed in g_2 and using published BV photometry. The *bona fide* CP stars, Be/λ Bootis stars and B[e] stars are indicated.

2. Observations and Data Reduction

We recently carried out a survey of almost the complete SMC in the g_2 filter. About 25% of the area covered was also observed in g_1 and y in order to investigate further the a-indices based on various colours. The CCD photometric measurements were obtained with the ESO 1.54-m Danish and 2.2-m MPG telescopes.

The CCD reductions were performed with standard IRAF v2.16 routines. Each image was corrected for bias and dark, and was flat-fielded. The photometry is based on PSF fitting. For each image, at least 20 isolated stars were selected to calculate the individual PSFs. Because of instrumentally induced offsets and different air masses between the single frames, the photometric reduction of each frame was performed separately. The measurements were then averaged and weighted by their individual photometric errors.

Calculation of Δa needs a colour index sensitive to effective temperature, such as $(g_1 - y)$, Johnson $(V - I)$, $(B - V)$, or Strömgren $(b - y)$. With those measurements, the index a can be calculated as $a = g_2 - [(B + V)/2]$ (or with any other colour indices).

The final step is to normalise a with the index a_0 of a non-peculiar star of the same colour, in order to compare different peculiar (or deviating) stars with each other. The photometric peculiarity Δa index is defined as $\Delta a = a - a_0$ (colour).

3. Results and Outlook

Figure 1 presents the results of a Δa survey of one field of the SMC using our g_2 measurements, together with Johnson BV colours taken from the OGLE-II fields (Udalski *et al.* 1998). The normal for non-peculiar stars is defined as ± 15 mmag from the mean.

As can be seen, we found only a small number of objects (about 0.5%) in this region which are *bona fide* CP stars. This is a very small percentage compared to the value of the Milky Way (up to 15%). However, an incidence that low in the LMC had already been discovered (Paunzen *et al.* 2014), and supports the fossil theory as the origin of the stable stellar magnetic field; the global magnetic field of the SMC is much weaker than in the Milky Way. It is possible that the lower global metallicity also plays a role, though that has not yet been confirmed by theory.

There have also been detections of a number of *bona fide* Be and metal-weak stars (compared to the metallicity of the SMC). Three of those detections were already known as Be stars (Paul *et al.* 2012), thereby constituting a valuable test for the reliability of our observations.

The metal-weak A-stars (known as λ Bootis stars in the Milky Way) are separate from the Be stars because the are cooler, and they stand out as a group among the CP stars of the upper main-sequence. The group is a small sub-set (only 2 per cent) of late-B to early-F stars and show moderate to extreme surface underabundances (up to a factor 100) of most Fe-peak elements but solar abundances of the lighter elements C, N, O and S. Several members of the group exhibit a strong infrared excess, and evidence of a disk (Murphy & Paunzen 2017).

To explain the peculiar chemical abundances, Venn & Lambert (1990) suggested selective accretion of circumstellar material. One of the principal features of that hypothesis is that the observed abundance anomalies are restricted to the stellar surface. On the basis of that hypothesis, Kamp & Paunzen (2002) and Martinez-Galarza *et al.* (2009) developed models which describe the interaction of the star with its local interstellar and/or circumstellar environment, whereby different degrees of underabundance are produced by different amounts of accreted material relative to the photospheric mass. The fact that the fraction of λ Bootis stars on the main-sequence is so small would then be a consequence of the low probability of a star–cloud interaction within a limited parameter space. For example, the effects of meridional circulation dissolves any accretion pattern a few million years after the accretion has stopped. Until now, no sound statistical analysis of metal-weak main-sequence stars has been performed for the SMC.

We know that only B[e] stars exhibit such extreme negative Δa values as those shown in Figure 1 (Paunzen *et al.* 2017). B[e] stars exhibit a NIR excess (due to the presence of surrounding hot circumstellar dust) and also forbidden lines in their spectra. They are most important for understanding stellar formation and the evolution of high-mass stars (Kraus *et al.* 2017). Unambiguous photometric detection of them on a large scale would be a big step towards analysing their characteristics, because only a few of them are known in the Magellanic Clouds (Levato *et al.* 2014).

Our next step is the publication of our survey in g_2 of the complete SMC, i.e., the first study of the λ 5200 Å region. It will increase significantly the number of known classical CP, Be/Ae/B[e] and metal-weak stars, enabling us to study the overall characteristics of these groups in comparison with their Galactic counterparts. Furthermore, we will investigate the photometric behaviour of cool giants in order to see if peculiarities in the given spectral region exist there too.

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