From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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The Abundances of Chemical Elements in the Atmospheres of K-supergiants in the Small Magellanic Cloud and Arcturus

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Abstract. The results of a spectrum synthesis analysis of elemental abundances derived from the high-resolution CCD-spectrograms of the SMC red supergiant stars PMMR23 and PMMR39 (stars 23 & 39 in the catalogue Prevot *et al.* 1983) are presented. The abundances of 35 elements in the atmosphere of PMMR23 have been obtained. Elements with atomic numbers Z<56 are deficient with respect to the solar abundances. The mean underabundance is about –0.7 dex. The abundances of elements heavier than barium are close to the solar value. In the case of PMMR23, the atmosphere is enriched in elements heavier than barium which show abundances close to the solar value. These abundances can be explained as a combination of *r*- and *s*-processes. In PMMR39, all the 20 studied elements present abundances deficient with respect to solar values The abundances of 31 elements with Z > 30 are determined in the atmosphere of Arcturus.

Keywords. stars: abundances; stars: individual (PMMR23, PMMR39, Arcturus); nucleosynthesis; galaxies: stellar content; galaxies: individual (Small Magellanic Cloud)

In the present paper we give a short summary of the abundance determination in the atmospheres of three stars born outside the Galaxy. The first two stars are PMMR23, PMMR39, members of Small Magellanic Cloud (SMC), the third one being Arcturus which was also found to be born, with its kinematic group, outside the Galaxy (Navarro *et al.* 2004).

The abundance analysis is performed on the basis of the spectra of PMMR23 and PMMR39, taken at the 3.6 meter ESO La Silla telescope by Hill (1997), the Arctutus spectral atlas (Hinkle *et al*, 2000, Griffin, 1968), and the Liege solar atlas (Dellbouille *et al.*, 1973). The line identification is based on a comparison between the observed and synthetic spectra of the stars. The abundances of chemical elements are calculated using the spectrum synthesis method, as detailed description in Gopka *et al.* (2004) or Yushchenko *et al.* (2005). Peterson *et al.* (1993) atmosphere model is used for Arcturus. New atmosphere parameters are found for PMMR23 ($T_{\rm eff} = 4240$ K, $\log g = 0.12$, $v_{\rm micro} = 3.1$ km s^{-1}) and PMMR39 ($T_{\rm eff} = 4250$ K, $\log g = 0.16$, $v_{\rm micro} = 2.5$ km s^{-1}).

The abundances in PMMR23 were compared with scaled solar *r*- and *s*-process abundance distributions. All details about the s-process model and abundance calculations

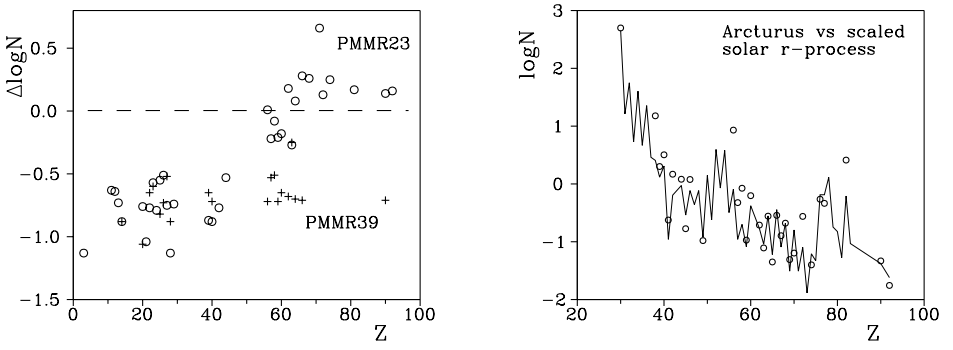

Figure 1. The abundance patterns of PMMR23 (left panel, circles) and PMMR39 (left panel, crosses) with respect to the Sun. The Arcturus (right panels, circles) abundances are compared with the scaled solar *r*-process abundances (line). The abundances of U in PMMR23 and Arcturus and Th in PMMR39 are upper limits.

can be found in Goriely and Mowlavi (2000). PMMR23 is found to be enriched in both s- and r-elements, and enters the class of s+r-enhanced stars, recently observed and debated in the literature (e.g Cohen *et al.* 2003). In contrast, the abundances in PMMR39 are deficient with respect to solar values for all elements (Fig. 1, left panel). This case shows the spread of possible abundance patterns in SMC. The parameters of PMMR23 and PMMR39 are practically the same, but the chemical composition is significantly different. The Arcturus abundances (Fig. 1, right panel) agree rather well with the scaled solar system *r*-abundance distribution, though large deviations are observed for Sr, Ba, La, Ce, Hf, Pb. All these elements, except Hf, have a large *s*-process contribution to the solar abundance (more than 75%). For Hf this fraction is around 50%. An s-process contribution can therefore not be excluded.

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