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Cepheids as Swiss army knives for Milky Way archaeology

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Abstract. Cepheids are excellent stellar tracers: they are bright enough to be observed even at large distances; their distances can be accurately determined via period-luminosity relations; their spectra contain numerous lines that enable us to derive abundances for many α, iron-peak or neutron-capture elements. Classical Cepheids are yellow supergiants that trace the young populations ($\leqslant$ 300 Myr); Type II Cepheids are post Horizontal Branch, low-mass, Population II stars ($\geqslant$ 10 Gyr). Both can be used for many purposes in Milky Way archaeology.

Keywords. stars: variables: Cepheids / stars: abundances / Galaxy: disk / stars: mass function

1. Abundance gradients for neutron-capture elements

Abundance gradients provide sound constraints for the chemodynamical evolution models. In da Silva *et al.* (2016), we determined the abundances of 5 neutron-capture elements (Y, La, Ce, Nd, Eu) in 73 new Cepheids. The hyperfine structure was taken into account for Y, La and Eu. Results were complemented by similar abundances provided by our group or found in the literature. Homogeneous distances were derived from period-Wesenheit relations and near-infrared photometry from Inno *et al.* (2013). The typical uncertainty on the individual distances is ∼5%. Our final sample contains 435 Cepheids covering a broad range of pulsation periods ($0.36 \leqslant logP \leqslant 1.54$) and Galactocentric distances ($4.6 \leqslant R_G \leqslant 14.3$ kpc). We found well-defined abundance gradients for the 5 neutron-capture elements. The slope is $\sim -0.025 \pm 0.004$ dex/kpc except for Y, for which it is surprisingly a factor 2 steeper, and similar to the Fe gradient. We found a small scatter around the mean gradient and no well-defined slope in the [element/Fe] vs logP plot (where logP is a proxy for age). We then conclude that the chemical enrichment across the Galactic thin disk is characterized by firm spatial and temporal homogeneity.

2. Chemistry of type II Cepheids

It is not easy to distinguish between classical and Type II Cepheids, and between the subclasses of Type II Cepheids (BL Her, W Vir, RV Tau stars). From several arguments, including chemical composition and the presence of emission features in the Hα and in the 5875.64Å He *I* lines at certain phases, Lemasle *et al.* (2015) concluded that HQ Car and DD Vel are Type II Cepheids of the W Vir subclass. DD Vel shows the signature of (mild) dust-gas separation: the more volatile elements have abundances similar to those of an average thick-disk star (Reddy *et al.* (2006)), while the refractory elements are underabundant. In a qualitative scenario developed for RV Tau stars by Waters *et al.* (1992), the dust-gas separation occurs when radiation pressure traps dust grains in a circumbinary disk while some of the gas (deprived from dust) is re-accreted onto the star via the viscous disk that allows for transfer of angular momentum.

3. First metallicity estimate for a Cepheid beyond the Bulge

Double-mode Cepheids pulsate not only in the fundamental mode, but in 2 modes simultaneously. The period ratio P_1/P_0 for the fundamental and the first overtone mode is metallicity-dependent. In Kovtyukh *et al.* (2016), we determined the detailed chemical composition of 18 out of 24 known double-mode Cepheids in the Milky Way and calibrated a new relation between [Fe/H] and P_1/P_0. Using this relation we provided the first metallicity estimate ([Fe/H]=−0.39 dex) for a Cepheid located beyond the Bulge. This star was discovered by Feast *et al.* (2014), possibly in a flared outer disk in the far side of the Milky Way, and identified as a double-mode Cepheid by OGLE-III.

4. Constraining the thin disk Initial Mass Function (IMF)

The IMF plays a crucial role for galaxy evolution. In Mor *et al.* (2017) we have constrained the IMF of the Milky Way thin disk by comparing Solar neighborhood observations (Tycho-2 data and catalogs of classical Cepheids) with different variants of the Besançon Galaxy Model. Three statistical methods (absolute star counts, reduced Poissonian likelihood, probabilistic Bayesian approach) were used to search for the IMF that best reproduces the observations. They all favour a slope of α=3.2 for thin disk stars in the Solar neighborhood, excluding flatter slopes such as the Salpeter IMF (α=2.35). This is steeper than the canonical stellar IMF of associations and young clusters but consistent with the predictions of the Integrated Galactic IMF.

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