From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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[Fe/H] and [α/Fe] of cepheids in the outer galactic disk

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Abstract. We have derived [Fe/H] and [α/Fe] abudnances for Cepheids with Galactocentric distances of 11 to 17 kpc. The stars are as metal-poor as much older open clusters at comparable distances. Like the clusters, and despite their youth, the Cepheids also show enhanced [α/Fe] abundances indicating enhanced contributions from SNe II relative to the Solar neighborhood.

Keywords. Galaxy: abundances, Galaxy: disk, Galaxy: formation

1. Introduction

In 1997 we began a program to study young and old stars of the outer Galactic disk, in order to explore its star formation history via heavy element abundances and elemental abundance ratios. SNe II are thought to overproduce r-process elements such as Eu and "α" elements such as Mg, Si, Ca, and Ti, relative to iron, which comes from both SNe II and the slower-to-appear SNe Ia. Our targets have included old open clusters and field stars (Yong, Carney, & de Almeida 2005; Carney *et al.* 2005; Carney & Yong 2005). Here we show results for a sample of young but easily identified stars: Cepheid variables.

2. Observations & Analyses

The 4-meter telescopes and échelle spectrographs at Kitt Peak National Observatory and the Cerro Tololo Inter-American Observatory were used, and the spectra had signal-to-noise levels in excess of 100 per pixel, and resolving powers, $\lambda/\Delta\lambda$, of about 32,000. Abundances analyses followed the same methods as described by Yong *et al.* (2005): classical fine analyses were done employing enforced excitation potential equilibrium for the Fe I lines (to set $T_{\rm eff}$), as well as enforced ionization potential equilibrium, by comparing Fe I and Fe II abundances (to set log g). Microturbulent velocities were determined by enforcing abundance measure insensitivity to equivalent widths of Fe I lines. ATLAS9 model atmospheres were calculated for each step in all analyses.

Distances were estimated using infrared photometry to reduce reddening uncertainties. The $M_{\rm K}$ vs. log P relation of Madore & Freedman (1991) was adopted, and $< K >$ magnitudes were obtained from 2MASS measurements, corrected to a mean magnitude following the prescriptions of Soszyński, Gieren, & Pietrzyński (2005).

Here we show results only for the stars with periods of greater than 2.5 days to minimize problems with overtone pulsators (see Alcock *et al.* 1995).

3. Results

First, we note that S. Andrievsky and his colleagues (Andrievsky *et al.* 2002a,b,c; Luck *et al.* 2003) have studied a large sample of local and distant Cepheid variables, and we

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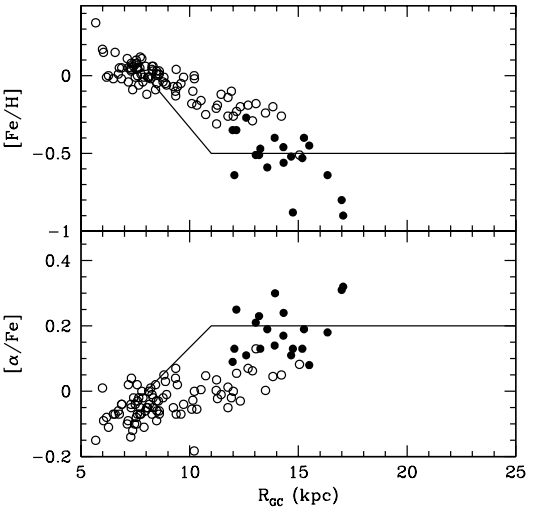

Figure 1. [Fe/H] and [α/Fe] results for cepheid variables taken from Andrievsky and collaborators (open circles) and our Cepheids with $P > 2.5$ days (filled circles).

employ their results here. Systematic differences are small. Figure 1 shows our results. The solid lines are schematic fits to our prior results for old open clusters and field stars.

Three points emerge. 1. The younger Cepheids reach the same low [Fe/H] values as the much older clusters and field stars, but at larger Galactocentric distances, 14 kpc rather than 11 kpc. 2. There is a significant spread in [Fe/H] and [α/Fe] among the most distant cepheids. 3. The [α/Fe] abundances of *both* the old stars and the young Cepheids in the outer disk are enhanced relative to Solar neighborhood stars.

4. Conclusions

One simple interpretation that explains Figure 1 is that the outer Galactic disk has been growing steadily, perhaps by episodic accretion events involving metal-poor stars and gas. The accretion process itself may stimulate bursts of star formation, enhancing the role played by SNe II and thereby explaining the enhanced [α/Fe] ratios.

Acknowledgements

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