Galaxy Mergers: A Search for Chemical Signatures

Inese I. Ivans
Dept. of Astronomy & McDonald Observatory, Univ. of Texas at Austin

Bruce Carney
Dept. of Physics & Astronomy, Univ. of North Carolina at Chapel Hill

Luisa de Almeida
Dept. of Physics & Astronomy, Univ. of North Carolina at Chapel Hill

Chris Sneden
Dept. of Astronomy & McDonald Observatory, Univ. of Texas at Austin

Abstract. We have gathered high resolution échelle spectra for more than two dozen high-velocity metal-poor field stars, including BD+80 245, a star previously known to have extremely low [\(\alpha/\text{Fe}\)] abundances, as well as G4-36, a new low [\(\alpha/\text{Fe}\)] star with unusually large [\(\text{Ni}/\text{Fe}\)]. In this kinematically selected sample, other chemically anomalous stars have also been uncovered. In addition to deriving the \(\alpha\)-element abundances, we have also analysed iron-group and \(s\)-process elements. Not only does chemical substructure exist in the halo, but the chemical anomalies are not all the same within all elemental groups.

Recent kinematic and photometric evidence depicts an increasingly complicated picture of early galaxy formation, and of stellar debris left behind by an unknown number of passages and mergers by satellite systems of the Milky Way. In addition to kinematic similarities, chemical “signatures” may identify these merger/accretion events. A number of very high-velocity metal-poor field stars have been discovered that possess very unusual abundance ratios of \(\alpha\)-elements (Mg, Si, Ca and maybe Ti) to iron. The stars discovered to date all have large apogalacticon distances—these stars may have originated within a satellite galaxy or galaxies that experienced a different nucleosynthetic chemical evolution history than the Milky Way and which were later accreted by it.

Did the nucleosynthetic histories of the dwarf galaxies produce abundance ratios different from those found in the halo of the Milky Way? Preliminary results of chemical abundances of metal-poor stars in the Sagittarius dwarf spheroidal galaxy (Smecker-Hane et al. 1998) as well as in the Draco, Sextans and Ursa Minor dwarf galaxies (Shetrone et al. 2000), for the most part, seem to be similar to those of Galactic halo stars. In the more metal-rich Sgr stars, however, Smecker-Hane et al. find subsolar elemental ratios indicative of an evolution consistent with enrichment from SNIa with declining SNII enrichment. This
is the kind of nucleosynthetic SNIa enrichment, as described by Unavane et al. 1996, one might expect from a system with a low star formation rate, along with possible recycling of nucleosynthetic products through successive stellar generations. Dwarf galaxies today may not be representative of the dwarf galaxies of the past. If mergers of dwarf galaxies at earlier times involved those less massive than the surviving satellites seen today, it is possible that the mergers left behind signatures of even less star formation and greater SNIa enhancements.

In figure 1, we illustrate the abundances of some of the low-\(\alpha\) stars of abnormal abundances in the context of the rest of our sample and other stars of comparable metallicities from the literature. For stars we have analysed in common with those in the literature, our abundances are in accord.

We confirm that there appears to be a correlation between Na and Ni abundances with respect to iron in halo stars (Nissen & Schuster 1997). However, the trend of Na with Ni for the low-\(\alpha\) stars seems to have a different slope and this is not understood. We are currently exploring correlations between various abundance signatures with kinematics with the aim of unravelling the nucleosynthesis history that produced the unusual abundance ratios.

Chemical substructure in the halo as described here is not currently explained in models of galactic chemical evolution. With a sufficiently large representative halo sample, one can determine the fraction of chemically anomalous stars in the metal-poor halo and investigate their origins. By employing the kinematical information for these objects, we will also investigate whether the unusual \([\alpha/Fe]\) ratios have been found in a large enough sample of stars to identify their origins.

References

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Figure 1. The abundances of G4-36 (*) and BD+80 245 (⋆) from this study, HD139439/40 (□) from King 1997, and globular clusters Pal 12 and Rup 106 (△) from Brown et al. 1997, along with some of our other stars (●) as well as results (○) from studies by Magain 1989, Gratton & Sneden 1991, McWilliam et al. 1995, 1998, Ryan et al. 1996, Carney et al. 1997, Nissen & Schuster 1997, Hanson et al. 1998, Stephens 1999, Burris et al. 2000, Fulbright 2000 and James 2000. Plotted are abundances of barium (an s-process element), nickel (r-process), titanium (sometimes r-process; sometimes an α-element), calcium, silicon, magnesium (all α-elements) and sodium. These plots illustrate the unusual nature of some of the chemically anomalous halo stars (eg. most α and Ba abundances) and that these low-α stars do not exhibit the same anomalies in all element groups (eg. Ni and Ti). Note the change in scale for the plot of [Ba/Fe] abundances.