A COMPOSITION GRADIENT IN THE GALACTIC DISK

K. A. Janes
Astronomy Department, Boston University, Boston, MA 02215

A number of recent investigations have demonstrated that the heavy element abundance in galactic disks decreases with increasing distance from the center. Although there is little question that the composition in the outermost parts of galactic disks differs from that in the inner regions, the precise nature of the presumed gradient in our own galaxy remains undetermined. At the present time, the most specific evidence for a gradient is based either on kinematics of stars in the solar vicinity (e.g., Janes, 1975 or Mayor, 1976) or on observations of distant H II regions (Hawley, 1977) and planetary nebulae (Peimbert, et al, 1977). Little is known about the variation of abundance ratios with position or the relation between stellar ages and the composition gradient. However, all three of these quantities (that is, the overall metallicity gradient, variation of abundance ratios and stellar age effects) can now be estimated from theoretical models of galactic evolution (for example, see Tinsley and Larson, 1977).

This report is a summary of an observational program to estimate directly the compositions of stars in distant parts of the galactic disk. Using DDO photometry, it is possible to estimate the metallicity of a rather faint K-giant star and therefore to survey typical stars across a substantial part of the galactic disk. There are, in fact, at least three characteristics of the DDO system which make it useful for studying galactic structure. First, the DDO metallicity index, δCN, correlates well with spectroscopic iron-to-hydrogen ratios. Second, the interstellar reddening to an individual K giant can be determined reliably. Finally, a star's absolute magnitude can be estimated from the photometric indices. This combination of qualities, together with the fact that K giants are intrinsically rather bright, make it possible to survey the galactic disk to a distance of three to four kiloparsecs from the sun.

Four different samples of stars were used to obtain the results for this project. Two of the samples consist of field stars at various distances along two lines of sight, one directed toward the galactic center and the other toward the galactic anticenter. The third sample

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consists of DDO photometry of red giants in disk (open) clusters located in all directions around the galactic plane, and the final sample is a compilation of ultraviolet excesses of red giants in a large number of clusters which have published UBV photometry. Each of the four samples shows some suggestion of a radial gradient in heavy element abundance.

The sample of field stars in the galactic center direction ($\ell = 0^\circ$, $b = -4^\circ$) shows the weakest evidence for a gradient, but even in this case, the more distant stars (i.e., those closer to the galactic center) are slightly more metal rich. Both the group of clusters with DDO photometry and the sample of field stars in the anticenter direction ($\ell = 182^\circ$, $b = 2^\circ$) decrease markedly in metallicity with increasing galactocentric distance, and in spite of large errors, the fourth sample, consisting of clusters with uv excesses, is consistent with a gradient as well. In both groups of clusters, the gradient toward the galactic center is less pronounced than the gradient in the other direction.

The results of this investigation are summarized in figure 1. The points represent the mean values of δCN for all the objects studied, grouped according to galactocentric distance, R. Because an excellent correlation exists between δCN and uv excess, it was possible to include the uv excess data in this figure by transforming it to δCN. There is no question that a gradient exists, but more significantly, the gradient becomes steeper in the outer part of the galactic disk. The index δCN has been calibrated in terms of [Fe/H], so it is possible to transform the data into a quantitative form. In the solar vicinity, the gradient is $d[Fe/H]/dR = -0.036$ kpc^{-1}, but beyond 11 kpc from the galactic center it becomes $d[Fe/H] = -0.10$ kpc^{-1}.

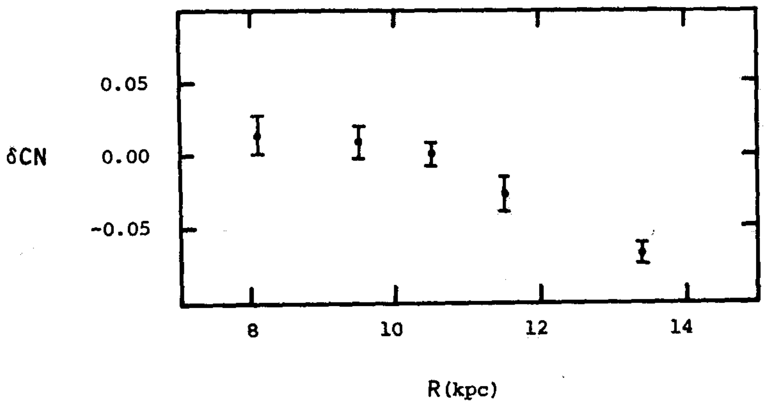

Figure 1 - Mean values of δCN for objects grouped according to galactocentric distance, R.

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These values are consistent with other recent determinations, including several reported in this colloquium, so that a local gradient on the order of -0.05 kpc^{-1} seems clearly established. The change in the gradient that can be seen in figure 1 has not been noticed before, but the overall appearance of the figure bears a striking resemblance to the theoretical abundance gradients derived by Tinsley and Larson (1977). While this does not prove that their model is the unique solution, it does provide strong support for Larson's dynamical collapse theory of the formation of galactic disks.

It is necessary to point out that although a good relation exists between δCN and [Fe/H], the index itself is actually a measure of carbon and/or nitrogen abundance. If the carbon abundance is assumed to be proportional to the iron abundance, then the existence of the apparently unique relation between δCN and [Fe/H] implies that [N/Fe] = α[Fe/H] where α is a constant which at the moment could have any value (including zero). The value of α if it can be determined would provide an important constraint on chemical evolution and nucleosynthesis models.

Using the cluster data, it is possible to make a preliminary statement about differences in the gradient as a function of the age of the stellar population. When the clusters are divided into equal groups, one containing the older clusters and the other the younger clusters, the old group shows a steep gradient and the young group a small gradient. This conclusion does, however, conflict with Mayor's (1976) results, and, in fact, the data is only marginally significant. Observations of more clusters are needed to resolve this conflict. It will be particularly important to obtain additional information about clusters toward the galactic center.

A more complete description of this program is in press (Janes, 1977). This research was supported in part by National Science Foundation grant AST76-01584.

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