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Chemical composition and kinematics of Galactic disk stars

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This paper has become a cornerstone of studies of the chemical composition of galactic disk stars and of its link to the galactic orbits of the stars. It is the first systematic homogeneous study of a large sample of stars, both for their detailed chemical compositions and for complete kinematical data, allowing their galactic orbits to be reconstructed.

A selection of 189 F and G stars was made from Strömgren *uvby*-β photometry, covering the full range of metallicity in the disk, favoring slightly evolved stars so as to be able to also get their ages and place them in a grid of internal structure isochrones. Full sets of kinematical parameters were collected to get the orbits of each target star in the Galaxy.

High S/N spectra at high spectral resolution taken at the 2.7m Mc Donald Observatory (Texas) and at the ESO 1.4m CAT telescope Coudé spectrograph, in several wavelength intervals, have allowed observation of 86 lines of the 11 elements O, Na, Mg, Al, Si, Ca, Ti, Fe, Ni, Y, Zr, Ba, and Nd. The spectra were analyzed using a new generation of model atmospheres, based on the opacity-sampling method instead of the opacity-distribution functions. This new grid gives an improved fit of the solar UV flux in the 1500–3000 Å, with the inclusion of a large number of previously unknown lines. It was the first time that a systematic homogenous analysis was done on such a large sample of stars, allowing the chemical composition of galactic disk stars to be connected with their kinematics with unprecedented accuracy.

The first impact of this paper was to show that the metallicity scatter in the local sample was not principally due to an age-metallicity effect, as expected by a progressive metallicity enrichment of the disk from the metallicity of the thick disk to its present metallicity. A second cause of scatter, linked to the kind of orbit of the star, studied by Wielen (1977), is the birthplace of the star. Stars with excentric orbits may have originated at various distances from the galactic center. The existence of a well-established radial metallicity gradient in the Galaxy, already found by the study of open clusters by Friel & Janes (1993), opens the possibity that the star comes from either a metal-richer or metal-poorer region than the solar neighborhood. The cause of this scatter was also studied in the paper and found to be too small to explain the full metallicity scatter at any given age. For example, stars with a nearly circular orbit, with radial distances within 7 to 9 kpc from the galactic center, and at any given age still show an intrinsic scatter of about 0.2 dex, in [Fe/H][1]. This may be explained by the heterogeneity of the interstellar medium, because the metallicity enrichment by local events are not followed by immediate mixing. Accretion of gas from outside can generate scatter, but also may help in producing a flat [Fe/H] versus age diagram, if the accreted gas is metal-poor.

If hardly any age-metallicity slope is seen for ages between 3 and 10 Gyr, a clear slope in the diagram [Fe/H] versus age exists for ages above 10 Gyr. This is obviously a signature of the start of the transition to the thick disk and halo populations.

Other sections of the paper deal with the behavior of other elements than Fe, in relationship with their nucleosynthetic sources. Particular attention is given to the α-elements, which are formed early by massive SNe II. Very clearly, Mg/Fe and O/Fe have similar behavior when plotted versus [Fe/H], whereas the α-elements Si and Ca have a somewhat reduced amplitude in the increase in Si/Fe and Ca/Fe with decreasing metallicity.

The element showing the strongest age-metallicity effect is barium, which is mainly produced by the neutron-capture *s*-process in AGB stars. The different timescale of this process explains this result, since it is linked to stars that are more similar in mass to the bulk of galactic stars. The behavior of the odd elements Na and Al were also obtained, and dwarf barium stars discovered.

We conclude by saying that this paper was the first to have studied a large enough sample and its abundance determinations were accurate enough above observational errors to have reached significant statistical conclusions on the trends and scatter of stellar abundances, in connection with the galactic orbital parameters of the objects.

References

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[1] The notation $[X/Y]$ means $\log(X/Y)_{\rm star} - \log(X/Y)_{\odot}$, X/Y being the abundance ratio of two elements X and Y.

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