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Empirical Relationships Between Gas Abundances And UV Selective Extinction

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The present paper summarizes several studies of gas-phase abundances in lines of sight through the outer edges of dense clouds. These lines of sight have $0.4 < E(B-V) < 1.1$ and have inferred spatial densities of a few hundred cm^{-3} . The primary thrust of these studies has been to compare gaseous abundances in interstellar clouds that have various types of peculiar selective extinction. To date, the most notable result has been an empirical relationship between the CN/Fe I abundance ratio and the depth of the 2200 Å extinction bump (see figure-1). It is not clear at the present time, however, whether these two parameters are linearly correlated or the data are organized into two discrete ensembles. Based on 19 samples and assuming the clouds form discrete ensembles, lines of sight that have a CN/Fe I abundance ratio greater than 0.3 (dex) appear to have a shallow 2.57 ± 0.55 bump compared to 3.60 ± 0.36 for other dense clouds and compared to the 3.6 Seaton (1979) average. The difference in the strength of the extinction bump between these two ensembles is 1.03 ± 0.23 . (Joseph, Snow, and Seab 1989).

Although a high-resolution IUE survey of dense clouds is far from complete, the few lines of sight with shallow extinction bumps all show preferential depletion of certain elements, while those lines of sight with normal 2200 Å bumps do not (see Joseph *et al.* 1986). Ca II, Cr II, and Mn II appear to exhibit the strongest preferential depletion compared to S II, P II, and Mg II. Fe II and Si II depletions also appear to be enhanced somewhat in the shallow-bump lines of sight. It should be noted that *Copernicus* data suggest all elements, including the so-called nondepletors, deplete in diffuse clouds (Snow and Jenkins 1980, Joseph 1988). Those lines of sight through dense clouds that have normal 2200 Å extinction bumps appear to be extensions of the depletions found in the diffuse interstellar medium. That is, the overall level of depletion is enhanced, but the element-to-element abundances are similar to those in diffuse clouds.

In a separate study, the abundances of neutral atoms were studied in a dense cloud having a shallow 2200 Å bump and in one with a normal strength bump (see Joseph 1986). Neutral atoms, which are selective tracers of the densest regions along the line of sight, are excellent interstellar probes since their absorption lines are normally free from saturation problems. While the abundances of neutral atoms depend on ionization equilibria (e.g., local flux densities and n_e), their ratios are meaningful because much of the uncertainty in the ionization equilibrium calculation cancels when two elements are compared. The abundances of neutral atoms in the shallow-bump line of sight indicate very strong (~ 1.0 dex) differences in the element-to-element depletions with respect to the integrated line-of-sight results. In the other line of sight, the Fe/P depletion ratio inferred from the neutrals is identical to the integrated line-of-sight measurements of the dominant, singly-ionized species. Previous studies of neutral atoms in diffuse clouds and in other dense clouds with normal extinction bumps also failed to find evidence of preferential depletion (Snow 1984, Snow, Joseph, and Meyer 1986).

Finally, there is one other potential difference, which may distinguish sight lines with shallow extinction bumps from those with ordinary ones. Despite several attempts to measure the 3.1μ ice feature in lines of sight with $E(B-V) \sim 1$, it has only been observed towards HD 29647, a line of sight with a shallow 2200 \AA extinction bump (Goebel 1983). Since it has been suggested that ice mantles on grains may suppress the 2200 \AA bump and since the observed preferential depletion of certain elements may be related to the formation of these ice mantles, a search for ice in lines of sight with shallow bump has been initiated (Joseph 1989).

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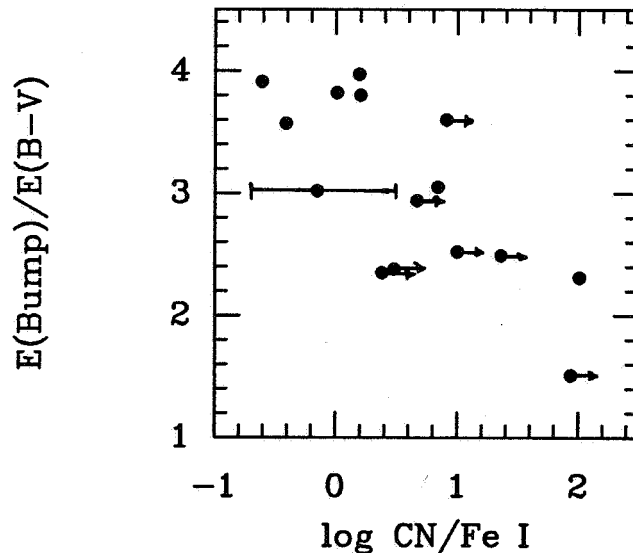


Figure 1: A scatter diagram, showing the relationship between the CN/Fe I abundance ratio and the strength of the 2200 \AA bump. Except for one line of sight, Fe I is not detected (typically at the 1 m\AA level) for all of the points with $E(\text{Bump})/E(B-V) < 3$. If these data form a linear correlation, many of the Fe I upper limits may be just above the detection threshold. If, however, future observations still fail to detect Fe I in the weak-bump lines of sight, then the data form discrete ensembles. The data are from Joseph, Snow, and Seab (1989, *Ap.J.*, **340**, 314). Most of the 2200 \AA Bump strengths are from Fitzpatrick and Massa (1988, *Ap.J.*, **328**, 734) or from Fitzpatrick (private communication).