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A survey of interstellar lines: radial velocity profiles and equivalent widths

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Abstract. An atlas of high resolution (R∼45,000) profiles of interstellar: atomic lines of KI (7665, 7699Å), NaI (D_1, D_2), CaII (H, K), CaI (4227 Å), molecular structures of CH, CH+, CN and the major diffuse interstellar bands at 5780 and 5797 Å, based on ∼300 echelle spectra of ∼200 OB stars is presented. Relationships between the reddenings, distances and equivalent widths of NaI, CaII, KI, CH, CH+, CN and diffuse bands are discussed. The equivalent width of KI (7699 Å) as well as of CH4300 Å correlate very tightly with E(B-V) in contrast to the features of neutral sodium, ionized calcium and the molecular ion CH+. The equivalent widths of the H and K lines of CaII grow with distance at a rate ∼250mA per 1 kpc. A similar relation for NaI is much less tight. The strengths of neutral potassium lines, molecular features and diffuse interstellar bands do not correlate practically with distance. These facts suggest that ionized calcium fills the interstellar space quite homogeneously while the other carriers mentioned above, especially KI, CH and these of diffuse bands occupy more and more compact volumes, also filled with dust grains. Apparently the carriers of narrow diffuse bands are spatially correlated with simple molecules and dust grains - all abundant in the so-called "zeta" † type clouds. The same environment seems to be hostile to the carriers of broad diffuse interstellar bands (DIBs) (like 5780 or 6284) and - to a certain extent - also to CaII, NaI and CH+.

Keywords. ISM: lines and bands, ISM: molecules

1. Results

The main results, and conclusions of this survey may be listed as follows:

• We demonstrate profiles of interstellar features derived from spectra of 200 reddened, mostly hot stars; radial velocities of the intervening clouds are measured and published;

• Our statistically meaningful sample of early type, reddened stars permits to propose the following picture: the vast interstellar space is filled with ionized gas, revealed by CaII H and K lines, their strength being directly proportional to the distance.Equivalent widths of H and K interstellar lines can be thus used to estimate roughly distances to absorbing clouds. Denser clouds may produce also NaI D1 and D2 lines; the latter are usually strong because of the very high oscillator strengths of the relevant transitions. The densest and compact clouds, producing most of the reddening, are populated with dust,

† Lines of sight, referred to as "sigma" clouds (because the line of sight toward sigma Scorpii is the archetype), are characterized by a low strength ratio of 5797/5780 DIBs. Conversely, in "zeta" clouds (after zeta Ophiuchi), one can expect a high ratio of these DIBs. Moreover, "zeta" type clouds show usually strong absorption lines of interstellar molecules such as CH, CH+, CN, C2, C3, etc., whereas the latter are weak in "sigma" type clouds (in many cases - below the level of detection).

neutral potassium atoms, molecules (like CH) and DIB carriers. Apparently molecular(?) carriers of DIBs can be formed and preserved under conditions similar to those required for well known simple interstellar molecules. Most likely, the presence of grains plays also an important role;

- The carrier of DIB5780 seems to be more resistant to the photo-ionization than that of 5797 (and probably – those of other narrow DIBs). On the other hand, DIB5780 as well as NaI, Ca II, and probably, CH+, is relatively weak while formed in environments rich in molecular species and narrow DIB carriers (”zeta” type clouds);
- Our sample of objects demonstrates a good coincidence with the HI distribution map. The sightlines between $\sim$90$\pm$20 degree are rich in interstellar matter and demonstrate a wide diversity of the profiles of interstellar lines;
- An independence of the reddening (E(B-V)) on distance (at least within the range $<$4 kpc) is demonstrated. This behavior may be due to the Local Bubble “wall” – the possibly main source of continuous extinction, molecular features and DIBs;
- We report for the first time the Doppler splitting of several DIBs (5797, 5850, 6614 etc.) in spectra of HD13256, HD219287, BD+58 2580, BD+59 2735); it clearly reflects that seen in the KI and CH line, supporting a close spatial relation between KI, CH and the DIB carrier; in several other cases very similar Doppler splitting, seen in NaI or CaII lines is not observable in any DIB profile;
- The profiles of interstellar features observed towards heavily reddened stars show spectacular Doppler-splitting but the radial velocities of disparate components, as well as the number of such components vary from species to species in the same spectrum;
- The plot presenting the distribution of radial velocities of interstellar clouds versus Galactic longitude is a promising tool for selecting objects with an unusual (rather circumstellar than interstellar) origin of the surrounding matter. An additional profit that may follow a complete survey of radial velocities derived from interstellar lines seen in spectra of stars in the Galactic plane vs. galactic longitude would be a reliable method of determining the Solar apex related to interstellar gas. Preliminary result revealed that the direction is close to the one postulated for the Solar apex versus interstellar gas, namely l=6 degree;
- The variation of DIB5780 profile with its growing intensity is demonstrated. This leads to a possible red-shift of the radial velocity value. This effect is likely to be found in many other diffuse interstellar bands;
- The small and dense clouds seem to be distributed mostly in the Galactic plane. Their opacity must be relatively high, and thus interstellar extinction does not grow in unison with distance. It depends strongly on how many such opaque clouds are situated along any specific sightline. As a technical remark, we can advice the measurements of either KI line or CH features to estimate the radial velocities needed to derive rest wavelengths of unidentified interstellar features. This is justified, since diffuse bands, potassium, CH radical, and DIB carriers seem to be spatially correlated.

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