MINOR CONSTITUENTS IN THE SOLAR WIND ORIGINATING FROM PLASMA-DUST INTERACTIONS

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It has long been known that high-energy keV neutral hydrogen and helium atoms are regular but very minor constituents of the solar wind (see, e.g., Gabriel, 1971; Holzer, 1977; Withbroe et al., 1982; and references therein). Ionization processes acting on these constituents in interplanetary space, mainly charge-exchange reactions, yield protons and singly ionized helium. While these "solar-wind-originating" minor constituents H, He and He^+ are generally taken into consideration in model calculations, as well as the heavy multiply-charged ions of coronal origin, a second class of minor constituents needs to be recalled and accounted for. This group of atoms, molecules, and atomic and molecular ions is generated by solar wind interactions with dust grains of the zodiacal cloud (Banks, 1971; Paresce and Bowyer, 1973; Holzer, 1977; Fahr et al., 1981). The main processes leading to the generation of these particles will briefly be described in the first part of this comment, while relevant methods of observation are discussed in the second part. A detailed analysis is given in Fahr et al. (1981).

Solar wind ions with energies in the keV range impinge on zodiacal dust grain surfaces and penetrate about 10 to 100 nm into the mineral. At the end of the particle trajectory, neutralization via electron capture will occur. The newly created neutrals are temporarily retained in the dust grain, undergoing diffusion processes and chemical reactions. Depending on the type of mineral, hydrogen atoms react to form OH, H_2O, H_2, and various carbon and silicon hydrides. Helium, of course, will stay in its atomic form. The dust grain cannot retain implanted particles indefinitely; saturation occurs on very short time scales compared to the typical residence times of the grains in a solar orbit. After saturation is reached, on the average one molecule or atom will be released from the dust grain surface for each impinging solar wind ion. For particles released from the surface by an evaporative process, the dynamics essentially are the same as those of zodiacal dust grains and can be calculated in an analogous manner. These particles are subject to strong interaction processes with the solar wind and with the solar radiation field. Most become dissociated and/or ionized and eventually form the singly-charged secondary solar wind constituents H^+, He^+, and H_2^+. In addition, singly-charged hydroxyl, carbon and silicon hydrides, and possibly other ions are formed in this process, depending on the type of parent grain. Only very few dust-generated neutrals will reach the orbit of the Earth as low-energy neutral particles.

Besides these surface-released particles, the processes of erosion, sputtering, vaporization, and sublimation of zodiacal dust grains generate atoms and molecules not containing original solar wind material, which in their singly-charged ionic forms subsequently are also incorporated into the solar wind and can be traced as very minor but heavy constituents. The most important ones should be ions of silicon and carbon compounds.

In principle, these solar wind-incorporated ions can be detected in-situ by mass spectrometers. To identify the dust-generated secondary ions in the background of the primary solar wind, the charge state of the heavy ions will be the most important factor. Ionization cross sections indicate that singly-charged ions incorporated into the solar wind flow will predominantly stay in this initial charge state. Since the zodiacal cloud source region is strongly compressed into the ecliptic plane (Figure 1), the secondary ion flow markedly decreases with heliographic latitude. If direct detection of the minor ions in the ecliptic plane can be accomplished, the spatial variation of this constituent monitored by spacecraft reaching higher heliographic latitudes (e.g. ISPM) would yield important information on the spatial distribution of zodiacal dust.

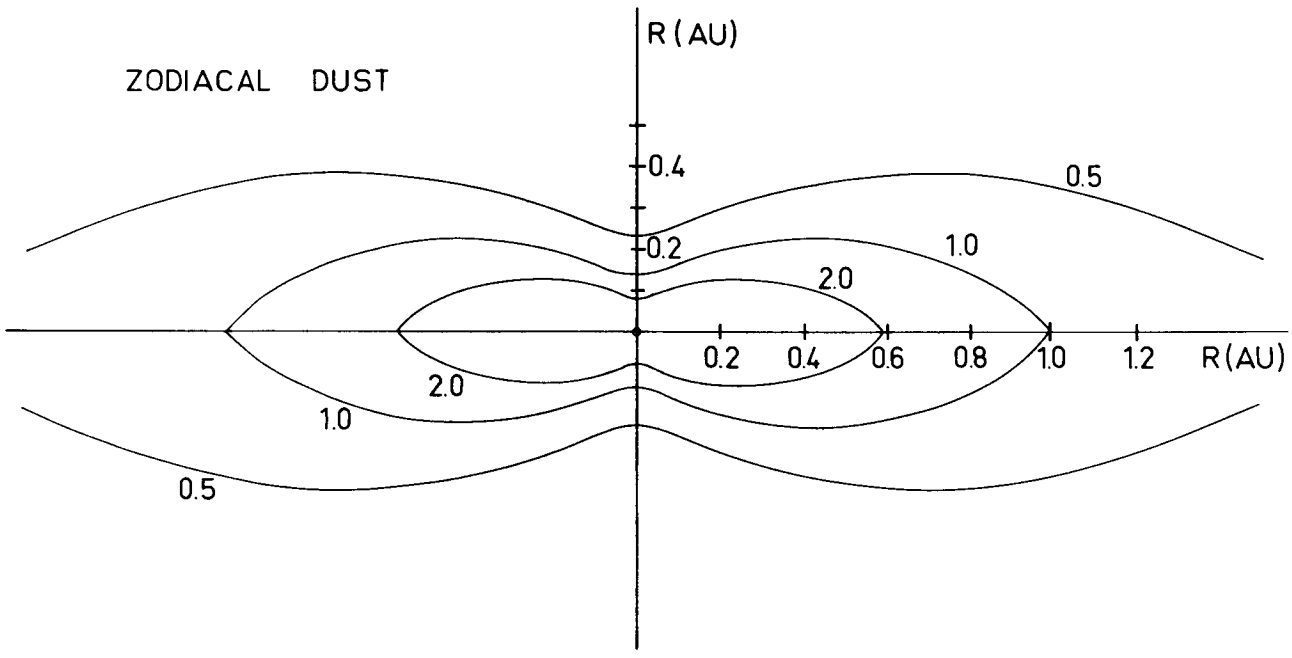

Figure 1. Isodensity lines of interplanetary zodiacal dust, according to a model derived from Helios measurements (Leinert et al., 1978).

Complementary observations of dust-deionized atomic hydrogen and helium can be accomplished by monitoring resonantly scattered solar photons at 121.6 nm (hydrogen) and 58.4 nm (helium). Due to sharp intensity increases of this resonance luminescence radiation with decreasing solar impact altitudes of the line-of-sight brought about by both density increases of the zodiacal cloud and increasing solar illumination with decreasing solar distances, observations are most promising in the immediate solar vicinity (line-of-sight solar offset angles $\approx 6^{\circ}$). For details see Fahr et al. (1981). Measurements of this EUV radiation are planned (Fahr et al., 1980), and if successful, would unambiguously point towards a relatively high dust density and thus to the actual existence of singly-charged minor ions in the solar wind which have not yet been reported in the literature. Possibly, some unexplained features in recent solar wind mass spectrograms could be reinterpreted taking into account the dust-generated ions.

References

Banks, P.M., Interplanetary hydrogen and helium from cosmic dust and the solar wind, J. Geophys. Res., 76, 4341, 1971.

Fahr, H.J., H.W. Ripken, and G. Lay, Inter-Zodiak: A high-apogee rocket experiment for the observation of dust-generated neutrals in the solar vicinity, ESA SP-152, 449, 1980.

Fahr, H.J., H.W. Ripken, and G. Lay, Plasma-dust interactions in the solar vicinity and their observational consequences, Astron. Astrophys., 102, 359, 1981.

Gabriel, A.H., Measurements of the Lyman-alpha corona, Solar Phys., 21, 392, 1971.

Holzer, T.E., Neutral hydrogen in interplanetary space, Rev. Geophys. Space Phys., 4, 467, 1977.

Leinert, C., M. Hanner, and E. Pitz, On the spatial distribution of interplanetary dust near 1 AU, Astron. Astrophys., 63, 183, 1978.

Paresce, F., and S. Bowyer, Resonance scattering from interstellar and interplanetary helium, Astron. Astrophys., 27, 399, 1973.

Withbroe, G.L., J.L. Kohl, and H. Weiser, Probing the solar wind acceleration region using spectroscopic techniques, Space Sci. Rev., 33, 17, 1982.