ELECTROSTATIC CHARGE OF INTERPLANETARY DUST GRAINS : NEW RESULTS

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ABSTRACT. A continuing program aimed at improving the determination of the charge of interplanetary as well as cosmic grains is presented. Recent data have been combined to generate two high-resolution solar spectra corresponding to the maximum & minimum of activity. The energy distribution of photoelectrons emitted by quartz grains under solar irradiation is calculated using the new laboratory measurements of Quemerais et al. (this volume). Finally, the method of Lafon, Millet and Lamy (Astron. Astrophys., 95,295, 1981) is used to find the electrostatic potential of these grains.

1. PHOTOELECTRIC EMISSION FROM FUSED-QUARTZ GRAINS

The differential flux of photoelectrons emitted by fused-quartz grains under solar radiation H (w) as a function of energy w in eV is expressed following Grard (1973) as

$$H(w) = Y(w)\ Q_{abs}(w)\ S(w)$$

where Y (w) is the photoelectric yield per absorbed photon, Q_{abs} (w) is the efficiency factor for absorption calculated with the Mie theory using the complex index of refraction of fused-quartz (Lamy, 1977) and S (w) is the differential solar photon flux.

Considerable progress has been achieved in measuring S (w) since the work of Grard (1973). The full-disk solar irradiance in the spectral range 1150 - 3200 Å is systemically measured by Mount and Rottman (1983) using rockets. These most recent results have benefited from improved calibrations and we retain those obtained on May 17, 1982, half-way in time between solar maximum and minimum but already representative of the minimum of the solar cycle. Solar maximum values were obtained on the July 15, 1980 flight.

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They are characterized by a large increase - by a factor 2 approximately - at wavelenghts below 1900 Å while they are equal to solar minimum values above. In the interval 300 - 1150 Å, we use the AFGL data which have a satisfactory overlap with the minimum values of Mount and Rottman. Figure 11 of Schmidtke (1981) allows to determine an average increase by a constant factor of 2.3 to generate solar maximum values. This approximation is not critical since this interval does not contribute significantly to the photoelectric effect. Figure 1 gives the combined data average in 20 Å intervals as a function of energy in the corresponding energy range 4 - 40 eV.

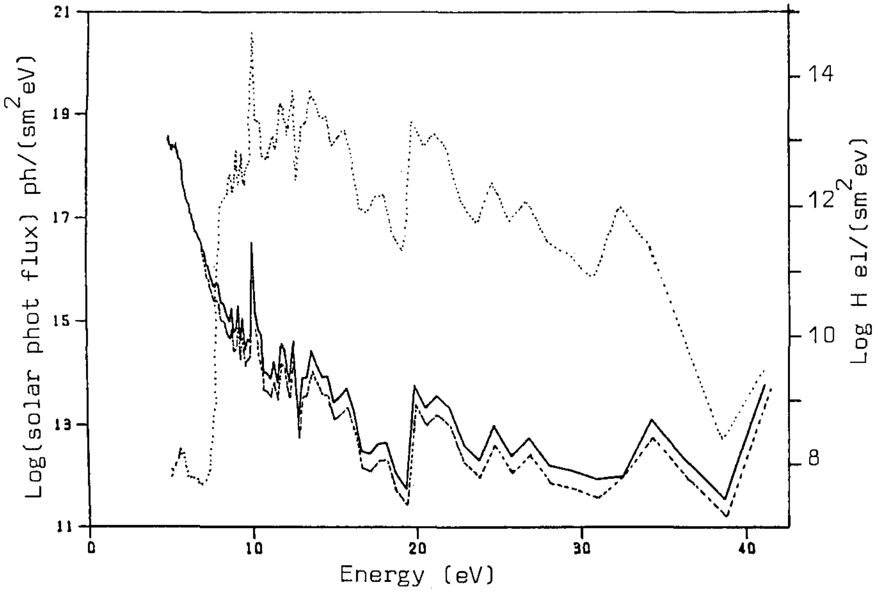

Figure 1. The differential solar photon flux for the maximum (solid line) and minimum (broken line) of activity (left scale) and the differential flux of photoelectrons H (w) (dotted line, right scale)

Using the laboratory measurements of Y (w) by Quemerais et al. (this volume), we obtain H (w) as illustrated in figure 1 for the case of solar minimum. These authors also measured the energy distribution functions of emitted photoelectrons f_w (ψ) for several energies w of incident monochromatic light. A best-fit analysis of their data has allowed us to obtain a parametric representation of the surface f (w,ψ).

After normalizing according to

$$\int_0^\infty f\ (w,\psi)\ d\psi = 1$$

we obtain the photoelectron energy distribution of fused quartz grains under solar irradiation

$$p\ (\psi) = \frac{1}{Is} \int_0^{\infty} f\ (w,\psi)\ \ H\ (w)\ dw$$

where Is, the saturation current density is expressed by

$$Is = \int_0^{\infty} H\ (w)\ dw$$

2. THE ELECTROSTATIC POTENTIAL OF INTERPLANETARY FUSED-QUARTZ

The problem of building a completely self-consistent model for a spherical body, for any surface effects and plasma compositions, with no approximation concerning the sheath was solved by Lafon, Lamy and Millet (1981). The effects due to the finite distance of the body from the enlightening stars were included. It was shown that the determination of the collected currents in the "Orbital Motion Limited" regime (Lafon, 1975) is exact for a grain at rest in the surrounding plasma and quite accurate in presence of drift velocities or of a disymmetry in the emission (or reemision) of particles by the body. The floating potential was shown to be unique in any case and its value was found whichever the preferential directions which can be different for particles of various species. Finally, the limits of validity of the model were discussed.

In the present article, we limit ourselves to the case of fused-quartz grains at 1 AU whose charge is the result of two competiting effects, the photoelectric effect and the collection of solar wind particles. The numerical program of Lafon et al. (1981) requires the following information:

2.1. Photoelectric effect

i) the electron volume density at the surface of the grain

$$No = \frac{8m}{e}\ \ Is \int_0^{\infty} \frac{p(\psi)}{\sqrt{\psi}}\ d\psi$$

where e and m are the charge and the mass of the electron.

Figure 2 shows how No depends upon the grains'radius (via Q_{abs}) in the interval 0.1 - 10 µm and upon solar activity as there is a factor 2 difference between the cases of solar minimum and maximum.

ii) the perpendicular velocity distribution function of the photoelectrons

$$F\ (v) = \frac{1}{2\pi} \left(\frac{m}{e}\right)^2 \frac{Is}{No} \frac{p(\psi)}{\psi}$$

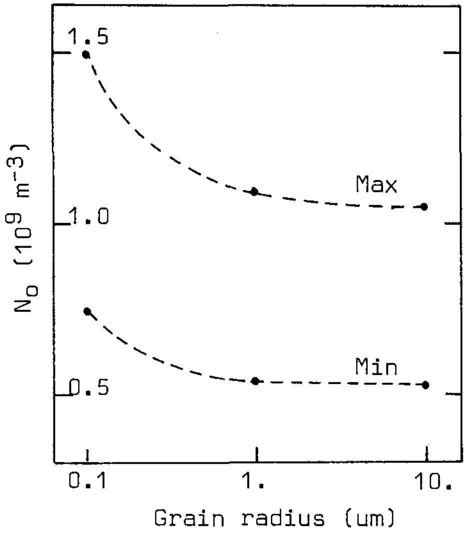

Figure 2. The electron volume density at the surface of fused-quartz grains

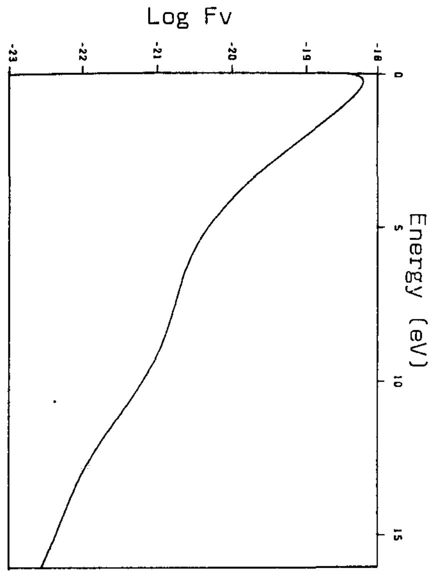

Figure 3. The perpendicular velocity distribution function of photoelectrons.

where the velocity is expressed as $v = (2e\psi/m)^{1/2}$. It is convenient to assume a maxwellian distribution and calculate the corresponding temperature

$$T = \frac{2e}{3k} \frac{\int_0^\infty \sqrt{\psi}\, p(\psi)\, d\,\psi}{\int_0^\infty \frac{p(\psi)}{\sqrt{\psi}}\, d\psi}$$

We found T = 1.2×10^4 K, constant within a few percents, i.e, independent of grains'size and of solar activity. The graph of the function F (v) (Figure 3) reveals that the assumption of a maxwellian distribution is strictly not correct. This will be improved in a forthcoming analysis, using for instance, two maxwellians.

2.2. Solar wind

The spatial density, the bulk velocity and the velocity distribution function for the solar wind particle species (electrons, protons and α - particles) are required. We retain the synthetic model of Millet et al. (1980) who considered the two "classical" situation of quiet solar wind (Q S W) and high-speed streams (H S S).

The final results for the potential of fused-quartz grains at 1 AU appear in table 1. One sees the influence of the size of the grain, of the solar activity and of the solar wind. Whatever these conditions, the potential lies in the range 2.5 - 5 Volts. It appears fairly constant in the size interval 1 - 10 µm but increases noticeably at 0.1 µm. There is typically a difference of a factor 1.7 between the minimum and the maximum conditions for both the sun and the solar wind.

Grain radius (µm)	0.1		1		10	
Solar Activity	MAX	MIN	MAX	MIN	MAX	MIN
Solar Wind HSS	4.93	4.08	4.72	3.83	4.68	3.79
Solar Wind Quiet	3.91	3.0	3.67	2.72	3.63	2.68

Table 1: electrostatic potential of Fused-quartz grains at 1 AU.

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