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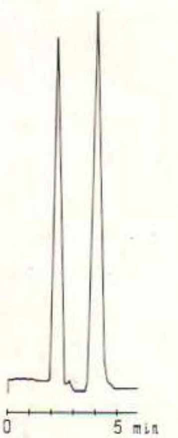
PHOBOS 2 AT MARS
The first results

ELECTROPHORESIS
product review

BIOSENSORS on line in HPLC with electrochemical detection

Acetylcholine/Choline · Hypoxanthine/Xanthine · Uric acid
Galactose · Glucose · Alcohols · Lactate · Oxalate
Catecholamines · Biogenic amines

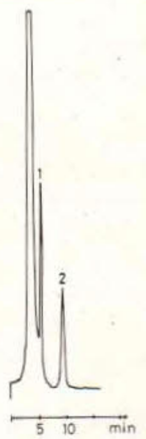


glucose and alcohol in wine

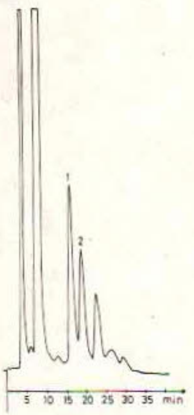
Biometra electrochemical detector EP 30

Even the smallest peak turns out

big



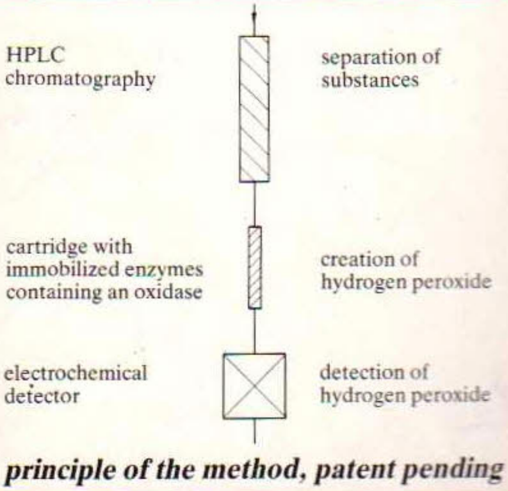
choline and acetylcholine
in tissue-homogenate



uric acid, hypoxanthine and
xanthine in urine

detection in the lower picomole range

a breakthrough in sensitivity and specificity



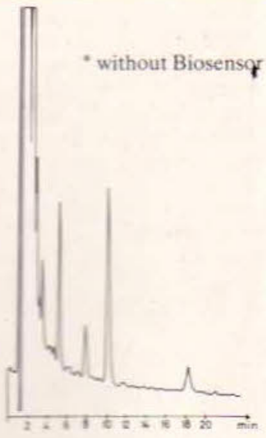
HPLC chromatography — separation of substances

cartridge with immobilized enzymes containing an oxidase — creation of hydrogen peroxide

electrochemical detector — detection of hydrogen peroxide

principle of the method, patent pending

* without Biosensor



catecholamines
in blood plasma

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able than the Earth's; also, the density and speed of the plasma found are different from orbit to orbit. This is probably due to the large amount of 'induced' magnetic field in the martian magnetosphere introducing most of the interplanetary magnetic field fluctuations into the tail.

The ion-velocity distributions found in the martian plasma sheet are also worthy of note. As an example, two two-dimensional spectra measured in the plasma sheet region during the second and the fourth elliptical orbit, at a distance of $\sim 1.5 \times 10^4$ km from the centre of Mars, are shown in Fig. 4. Although the mean tailward velocities of the plasma sheet ions were vastly different, the distributions are similar: the transverse (in the instrument's frame of reference) velocity spread or temperature is much higher than the longitudinal one and the resulting anisotropy of ~ 7 is probably one of the largest ever observed in a plasma anywhere. These velocity distributions are regarded as a very important diagnostic tool for the identification of the ion-acceleration processes at work.

Another interesting aspect of these E/q distributions is that they are only singly peaked. This strongly indicates that the observed plasma consists essentially of one ion species only. The high density of these heavy ions, which exceeds that of the heavy ions ($M/q \geq 3$) in the solar wind by about three orders of magnitude, leaves us no choice but to assume that they are of martian origin. The known composition of the upper martian ionosphere[3] from where they have probably been removed makes it highly probable that they are O^+.

It is of interest to estimate the total flux of heavy ions lost by the planet through its magnetotail. As the largest ion fluxes are observed in the plasma sheet, and we do not yet know much about plasma-sheet structure and variation with time, this initial evaluation must be regarded as tentative. We assume that we do not miss a major part of the ion flux as a result of the limited field of view of our instrument and take the width of the plasma sheet to be one martian diameter, $2R_M$, and to extend over the whole tail diameter of $\sim 4.5R_M$. From the data obtained during the second elliptical orbit the density and velocity of O^+ ions in the plasma sheet can be estimated to be of the order of $1.5\ \mathrm{cm}^{-3}$, and $150\ \mathrm{km\ s}^{-1}$, respectively. This results in a total tailward flux of O^+ ions of $\sim 2 \times 10^{25}\ \mathrm{s}^{-1}$, meaning that Mars would be deprived of all of its presently existing atmosphere after $\sim 10^9$ years, if the mass loss rate did not change with time and no other loss or gain processes existed. ☐

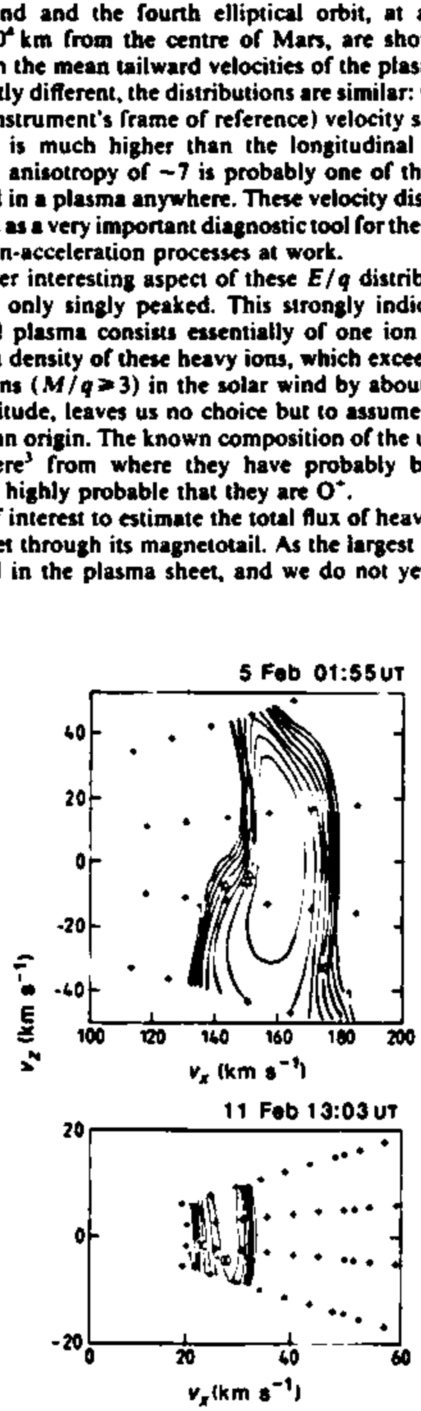

FIG. 4 Contour plots of count rates (to first order representing two-dimensional velocity distributions) obtained in the heavy-ion channel during the second (top) and fourth (bottom) orbit near the plasma sheet. Lines are spaced logarithmically by a factor of $\sqrt[3]{10}$ between adjacent contours. Crosses indicate the centres of the measurement channels. Conversion from E/q to velocity was made by assuming that the ions are O^+. V_x is the anti-sunward component of the velocity, and V_z is perpendicular to V_x. (The direction of V_z relative to the ecliptic plane cannot yet be given because of still missing information on the roll angle of the spacecraft.)

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1. Slavin, J. A. et al. J. geophys. Res. 94, 2383-2398 (1989)
2. Gringauz, K. I. Rev. Geophys. Space Phys. 14, 391-402 (1976)
3. Hanson, W. B. et al. J. geophys. Res. 82, 4351-4363 (1977)

Observation of electron and ion fluxes in the vicinity of Mars with the HARP spectrometer

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THE highly elliptical orbits of the Phobos 2 spacecraft, early in February 1989, proved particularly useful for plasma and field investigations of the martian environment. The low-altitude ($\sim$860 km) pericentres and the deep penetration into the magnetotail provided excellent opportunities to explore new and important regions. Here we present preliminary results of electron and ion measurements in the vicinity of Mars with the hyperbolic analyser in the retarding potential mode (HARP). HARP is a differential electrostatic analyser, simultaneously covering eight directions arranged in a fan-shaped geometry, in the anti-solar hemisphere. The angular resolution is $\sim$20°, the energy resolution $\sim$10%. During the first two elliptical orbits, to be discussed here, electrons from 3.4 to 550 eV and ions from 0.25 to 550 eV were measured in 25 and 50 logarithmic energy steps, respectively. The energy distribution of electrons in the magnetosheath was found to be generally characterized by two distinct peaks. A fairly hot electron component was discovered in the plasma sheet of the areo-magnetic tail.

The HARP differential electrostatic analyser allowed the measurement of charged particles within an energy (or, more precisely, energy per charge) range of $\sim$0.2-800 eV. The energy steps of the instrument were adjustable, that is, a more detailed study of some selected energy intervals was also possible by telecommand. Particles were measured simultaneously in eight sectors ($20° \times 10°$ each), symmetrically arranged relative to the anti-solar axis. The actual instrument package on the Phobos 2 spacecraft consisted of two independent and identical sensors. The sensors were mounted to point at 90° from each other. Each unit had four independent anodes. The combined directional

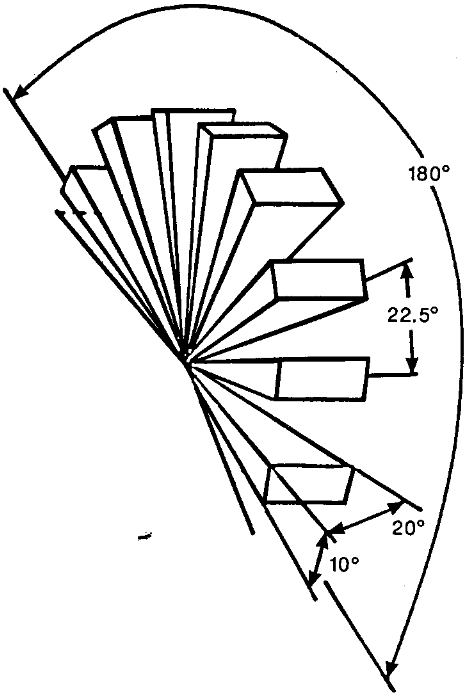


FIG. 1 Directional coverage of the HARP device (centred on the anti-solar direction).

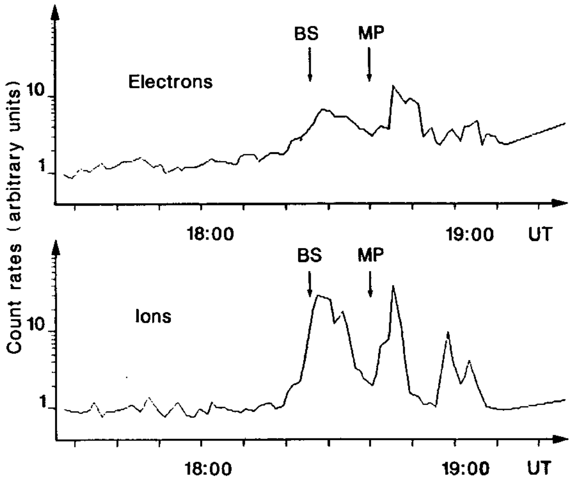


FIG. 2 Electron and ion total count rates as a function of time before and during Mars encounter on the first elliptical orbit of the Phobos spacecraft. BS, bow shock; MP, magnetopause.

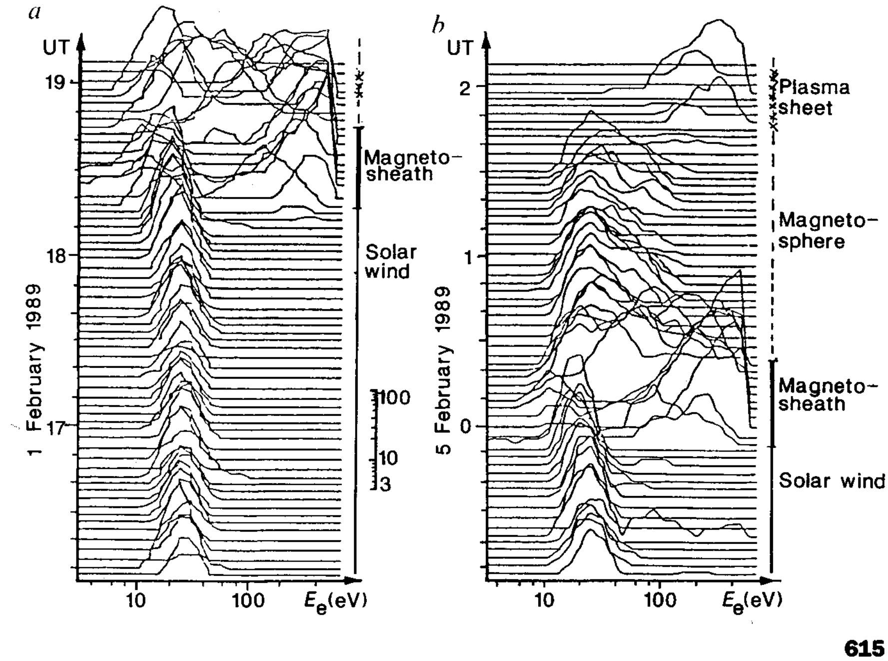
coverage is shown in Fig. 1. In the normal, three-axis-stabilized mode of the spacecraft, the viewing directions were in a plane perpendicular to the ecliptic. During the two orbits discussed here there was a slow rotation around the symmetry axis, and the precise attitudes as a function of time are not yet available. The Phobos HARP device[1,2] was specifically developed for this project. Earlier versions[3] were used in terrestrial ionospheric research.

The instrument's energy coverage during the first two elliptical orbits was as specified above. The integration period at each energy step was 1 s. The electron and ion measurements were made sequentially, which means that a complete electron/ion energy and angular distribution was obtained in 75 s. During the high-bit-rate telemetry regime covering the Mars encounters, practically full telemetry coverage was available.

The results of the electron measurements are highlighted here. Results of the ion measurements are only used for comparison in Fig. 2, where total count rates of electrons and ions (summed over energy and direction) are plotted as a function of time during the first elliptical orbit as the spacecraft approached the planet. The location of the bow shock and planetopause (magnetopause) depends on how these boundaries are defined in terms of the measured parameters. For example, the bow-shock crossing as indicated by the appearance of high-energy electron fluxes differed by ~5 min from the bow-shock position defined by the magnetic-field experimenters as the location of an observable jump in the magnitude of the magnetic field. Further and more careful intercomparisons and self-consistent definitions will be needed in the future to resolve these issues. In Fig. 2 we indicate the bow shock and planetopause/magnetopause crossing locations chosen by the magnetic field experimenters[4]; the increase of both electron and ion fluxes in the vicinity of the bow shock is clearly visible.

Spectral information provides a more detailed description of the dynamics of electron populations. As an example, the change of the spectral character of the measured electron flux in one directional channel (56° from the symmetry axis) is given in Fig.

FIG. 3 Variation in time of the energy spectra measured by the HARP device during *a* the first and *b* the second Mars encounter of the Phobos spacecraft.



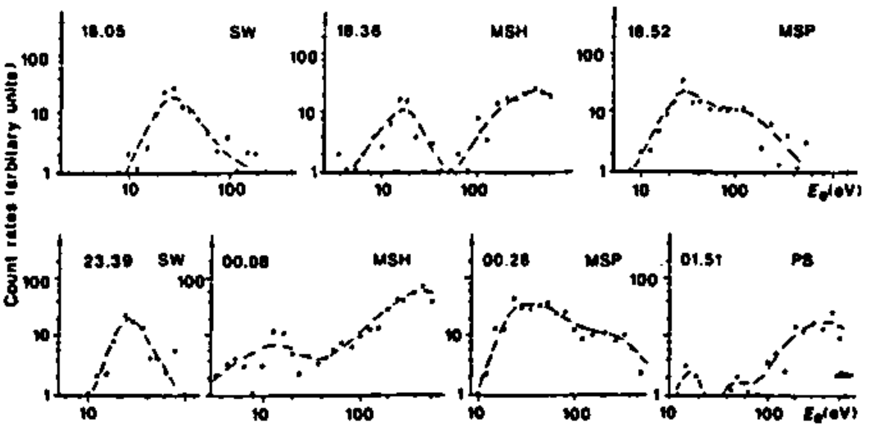


FIG. 4 Characteristic energy spectra (count rates as a function of energy) on the first two highly elliptic orbits. *a*, 1 February 1989; *b*, 4-5 February 1989. SW, solar wind; MSH, magnetosheath; MSP, magnetosphere; PS, plasma sheet.

3 for the first two elliptical orbits. (The 'spectra' represented here are really count rates proportional to energy flux, as usually measured by electrostatic analysers. The baselines represent 3 counts s^{-1} even when the measured count rate was lower.) For the first orbit, the sharp change in the spectral shape of the electron flux indicates a bow-shock position at 18:20 UT on 1 February, corresponding to a distance of ~1,500 km from the surface of the planet and a solar zenith angle (SZA) of 10°. For the second orbit, the spectral change, indicating the bow shock, occurred at 23:55 UT on 4 February, corresponding to a distance from the surface of ~1,700 km and a SZA of 11°. The periapsis of the orbits at a distance of ~860 km from the surface was at 18:39:37 UT on 1 February and 0:15:47 UT on 5 February.

The bow-shock crossing times determined from the HARP electron spectra are in reasonable agreement with those obtained by the MAGMA magnetometer[4] and the TAUS ion spectrometer[5]. The changes in the total flux and energy distribution of the measured spectra inside the bow shock are clear indications of changing plasma regimes. The solar-wind interaction processes at Mars are believed to be different from those at Earth and Venus, therefore the accepted terminologies used to delineate different regimes at these planets may not be quite appropriate to Mars. However, it is premature to coin new boundary definitions; therefore, we use here the terminology accepted for the terrestrial magnetosphere to label the different regions in Fig. 3, as delineated by the observed spectra. The data presented in Fig. 3 indicate that the electron spectra observed in the tail region of the planet are similar to those in the region just inside the bow shock. The energy spectra clearly show that electrons with energies ≫100 eV are present inside the bow shock in the magnetosheath.

Figure 4 presents typical spectra measured in various regions of the magnetosphere. (These spectra represent uncorrected count rates, so even single counts are included, in contrast to the baselines of Fig. 3.) In the magnetosheath the electron energy distribution is strongly non-maxwellian, often showing a distinct double peak; significant fluxes are present at energies beyond the energy limit of HARP. In the inner magnetosphere the electron fluxes were found to be generally more isotropic than in the magnetosheath. The corresponding energy distributions had a rather broad maximum, extending from ~20 to 150 eV. Most spectra are also characterized by a double-peak structure. In the shadow of the planet, the energy distributions of electrons, as mentioned above, are similar to those observed in the magnetosheath. This region, in the tail, is referred to as the plasma sheet. Before reaching the tail, the intensity of the electron fluxes dropped and showed strong fluctuations. Our identification of the plasmaphysical regions, as indicated in Figs 3 and 4, was supported by the TAUS ion measurements on the Phobos spacecraft[5].

Summarizing, the measurements of electron spectra along the orbit show sharp changes in both flux levels and in spectral shapes as the spacecraft crosses the bow shock, magnetopause and plasma sheet. The similarity of the observed electron spectra in the magnetosheath and the plasma sheet is likely to be an indication that the plasma sources and/or acceleration processes are similar in these regions. The plasma sheet with accelerated electrons in the inner magnetotail of Mars was detected for the first time with the HARP experiment on board the Phobos spacecraft.

The physical mechanisms responsible for the acceleration of the electrons inside the bow shock and the creation of double-peaked energy distributions are not known at this time. However, further analysis of the HARP data and careful comparisons with the observations of other field and particle experiments carried by the Phobos spacecraft, as well as with previous observations[6], will help to advance our understanding of Mars's plasma environment. ☐

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1. Szücs, I. T. *et al. Nucl. Instrum. Meth. Phys. Res.* A (in the press).
2. Király, P. *et al.* in *Instrum. Meth. Space Sci. Res.*, *Nauka* (in the press).
3. Shyn, T. W., Sharp, W. E. & Hays, P. B. *Rev. Sci. Instrum.* 47, 1005-1015 (1976).
4. Riedler, W. *et al. Nature* 341, 604-607 (1989).
5. Rosenbauer, H. *et al. Nature* 341, 612-614 (1989).
6. Gringauz, K. I. *Adv. Space Res.* 1, 5-24 (1981).

Energetic ions in the close environment of Mars and particle shadowing by the planet

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THE twin-telescope particle-detector system, SLED, aboard Phobos 2 recorded flux enhancements in the range 30–350 keV in the same general location in the close environment of Mars, over eight days at ~900 km altitude in three successive elliptical orbits. Here we present possible interpretations of these observations. Energy-related particle shadowing by the body of Mars was also detected, and the data indicate that this effect occurred in <20% of the 114 circular orbits around Mars because of the nutation