ENERGETIC PARTICLE PHENOMENA RECORDED BY THE SLED INSTRUMENT DURING THE PHOBOS MISSION TO MARS

S. M.P. McKenna-Lawlor[1], V.V. Afonin[2], K.I.Gringauz[2], E. Keppler[3], E. Kirsch[3], A.K.Richter[3], M. Witte[3], D. O'Sullivan[4], A. Thompson[4], K. Kecskemety[5], A.J. Somogyi[5], L. Szabo[5], A. Varga[5]

[1]Space Technology Ireland, St. Patrick's College,Maynooth, Ireland.
[2]Space Research Institute, Moscow, USSR
[3]Max Planck Institut fuer Aeronomie, Lindau, Germany
[4]Dublin Institute for Advanced Studies, Dublin Ireland
[5]Central Research Institute for Physics, Budapest, Hungary

Abstract

The particle detector system SLED aboard the Phobos Mission operated nominally during both the Cruise Phase and at Mars Encounter. The signature of a co-rotating interaction region recorded in space close to Mars is presented. An account is provided of the detection of flux enhancements (range 30-200 keV) at a location, approximately 900 km above the planet, over an eight day period, during three successive orbits. "Magnetic shadowing" close to the planet is also described.

The Phobos Mission The twin spacecraft of the Phobos Mission to Mars and its Moons were individually launched from the Baikonur Cosmodrome on July 7 and July 12, 1988. Ground contact with Phobos-1 was lost at the end of August, 1988. Phobos-2 however continued to transmit data to Earth and, after a 204 day flight, was transferred on February 1, 1989, into a series of four highly eccentric orbits around Mars, approaching to within 867 km of the surface of the planet. It was then transferred, first to an elliptical orbit of high pericenter, then to a circular equatorial orbit with an altitude of about 6330 km and finally, in March, to an orbit nearly synchronous with that of the Phobos Moon. Ground connection with the second spacecraft was lost on March 27,

SLED and the Phobos Mission The SLED detector system carried on Phobos 1 and Phobos 2, in each case comprised two semiconductor telescopes, each incorporating two silicon surface barrier detectors mounted coaxially. Count rate differences between the telescopes, (Te1 and Te2), which observed in the same direction but with open and foil covered apertures, allowed protons and electrons to be distinguished. within six channels each, over a range from 30 keV to a few tens of MeV. The geometric factor of each telescope was 0.21 cm^2 ster and the FOV axis, with a 40° apex angle, was in the ecliptic plane at 55° to the west of the sunward direction (the nominal direction of the interplanetary magnetic field at Mars). The SLED instrument is described in detail in McKenna-Lawlor et al., 1989.

Cruise Phase Data The data recorded by the two SLED instruments during the Cruise Phase were obtained during a period of transition from solar minimum to solar maximum dominated conditions 1988/89 (Cycle 22 began in September 1989). It is now understood from in-situ studies carried out over the last decade in the interplanetary medium, that interplanetary variability at solar minimum is associated with co-rotating structures and coronal holes whereas, at solar maximum, the dominant influence is provided by the consequences of energetic solar flares. These conditions therefore reflect quite different phenomenological circumstances.

During the Cruise Phase, the interplanetary medium, as monitored by SLED, was frequently greatly disturbed, see Fig.1, and detailed analysis of the complex data set obtained will be pertinent to the International Solar Interplanetary Variability Study (SIV), mounted by SCOSTEP, for the years 1988-89, to co-ordinate participation in interdisciplinary investigations of the interplanetary medium during the rising phase of the current cycle.

Fig.2 shows a single representative event recorded by SLED just at the end of the Cruise Phase when the spacecraft was injected into its first elliptical orbit about Mars. The interplanetary structure then present produced first a well defined enhancement (A), showing a steep-sided profile typical of a population of particles accelerated in a co-rotating interaction region. This enhancement was simultaneous in the data of Channels 1-4 of SLED and is illustrated as it appeared in Channel 4, Telescope 1 (0.6-3.2 MeV). It was suceeded by a major increase, simultaneous in all channels, followed by a long exponential decay. The exponential decay is typical of a flare related profile and it is suggested, since there was no time dispersion in the stimulation of other channels, that the particles concerned were trapped behind the co-rotating structure and recorded by SLED as the composite particle event swept past the spacecraft.

The Martian environment In the environment of Mars, when the spacecraft was traversing close elliptical orbits, well defined enhancements and depressions in fluxes, were in certain instances recorded. Fig. 3, shows particle fluxes measured with telescopes 1 and 2 during elliptical orbit 3 on February 8, 1989. These data show significant enhancements in flux, indicated for clarity by cross hatching, in the three lowest energy channels of Te. 1 (continuous line), followed by a depression in fluxes of about one order of magnitude, which was particularly clearly seen in the data of Te 1 channels 3, 4 and 5. The enhancement was not recorded in Te. 2 (dotted line). but the depressions in fluxes observed by Te 1 were also clearly present in the data of Te. 2, channels 3, and 4. During elliptical orbit 4, there was a telemetry gap close to pericentre. However, as shown in Fig. 4, from about 4 minutes thereafter the declining phase of a flux enhancement was present in the data of Te 1 . No special enhancement was observed in the data of Te 2. Again depressions in fluxes recorded by Te 1 in channels 2,3,4 and 5 had well defined counterparts in Te 2, channels 3, and 4. These decreases were energy dependent in both telescopes.

The enhancements illustrated represent two of a series of three such occurrences recorded during elliptical orbits 2, 3 and 4 in the same general location of the Martian magnetosphere over 8 days at approximately 900 km in altitude, see the drawn spike, labeled x, in Fig.5. which shows this position. Possible interpretations of these observations are presented in Afonin et al., 1989 and the effect is being carefully studied.. However, the statistical sample provided by three close orbits is so small, that, in the absence of unambiguous data concerning the overall structure of the ambient magnetic field, it will probably be necessary to await the results to be provided by SLED-2 on the Mars-94 Mission, before the implications of this result (which do not exclude the possibility that the enhancements represent signatures of quasi-trapped particle radiation) are fully understood. Investigation of the possibility that the enhancements may represent a response of the detectors to electromagnetic radiation scattered from the atmosphere of the planet, awaits precise information concerning the orbit parameters of Phobos and related spacecraft operations.

Screening of the aperture of the SLED instrument by the body of the planet over part of the orbit, to an extent controlled by parameters such as the magnetic field direction and the pitch angle distribution of spiraling particles (magnetic shadowing), appears to have been involved in produced the depressed count rates, In this connection, Fig. 6 provides a presentation of data, obtained while Phobos was in circular orbit at an altitude above the planet of about 6000 km. Mars is represented at the centre of the plot and the data of channel 4 (0.6-3.2 MeV) are displayed in a reference frame in which the sun is located along the + x axis and + y is to the south. Changes with time in the number of counts recorded are indicated by the magnitudes of vertical lines, representing individual readings, made at successive orbital locations. The data show counts recorded on March 12 and 13 when the sun was particularly active, and continued for many further days so to be. A well defined depression appearing in the top right hand quadrant of the data display on both records, may be ascribed to particle shadowing. (Gaps in counts reflect periods when the instrument was switched off due to spacecraft operations). The influence of magnetic effects in allowing particles to arrive at the detector in disturbed interplanetary conditions, even in situations where the solid angle of the aperture of the instrument was completely filled by the body of Mars, can be inferred from studies of the March data, The fact that decreases in particle fluxes were observed in less than 20% of circular orbital revolutions, appears to be an effect of the nutation of the spacecraft.

<u>References</u>

Afonin et al., 1989 Nature (in press)

S. McKenna-Lawlor et al., 1989 Nucl. Inst. and Meth. (in press)

Fig.1 Plot of Interplanetary variability recorded by Te 1, Channel 4 (0.6 - 3.2 MeV), log flux $(cm^2 \text{ sec ster keV})^{-1}$ vs. time (July 20, 1988 - March 03, 1989)

Fig.2 Particle data recorded by SLED in Te1, Channel 4 (0.6 - 3.2 MeV) from January 31 to February 05, 1989

Fig.3 Particle fluxes measured by Te 1(continuous line) and by Te 2 (dashed line) in the highly eccentric orbit of February 08, 1989

Fig.4 Particle fluxes measured by Te 1(continuous line) and by Te 2 (dashed line) in the highly eccentric orbit of February 11, 1989

Fig.5 Radial distance (in 1000 km) of the spacecraft from the x axis (Mars-Sun-Line) and the positions of the bowshock (BS) and pericentre (PC). The location of a long lived particle enhancement (>8 days) is indicated by the drawn spike, labeled x

Fig.6 Particle data recorded by SLED in Te 1 Channel 4 (0.6 - 3.2 Mev) on March 12 and 13 during circular revolutions 73 and 74 (+x, sunward direction, +y, southward direction). The look direction of the SLED instrument is shown, top right.

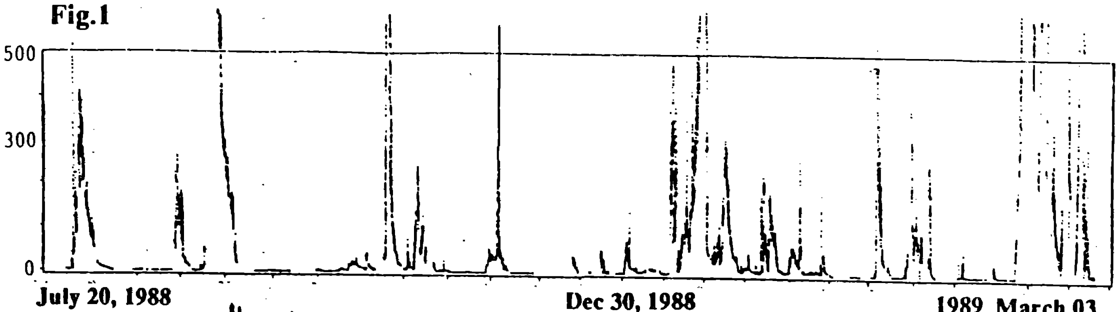
Fig.1
500
300
0
July 20, 1988
Dec 30, 1988
1989 March 03

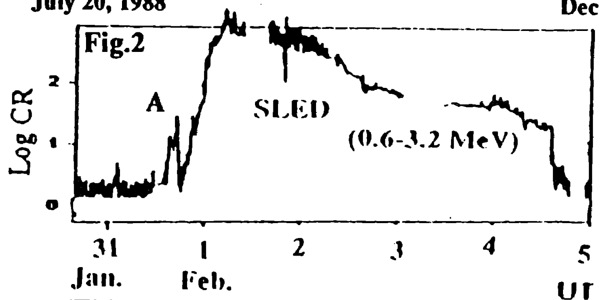
Fig.2
Log CR
A
SLED
(0.6-3.2 MeV)
31
Jan.
1
Feb.
2
3
4
5
UT

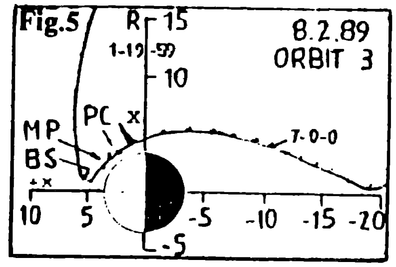
Fig.5
8.2.89
ORBIT 3
MP
BS
PC
10
5
-5
-10
-15
-20

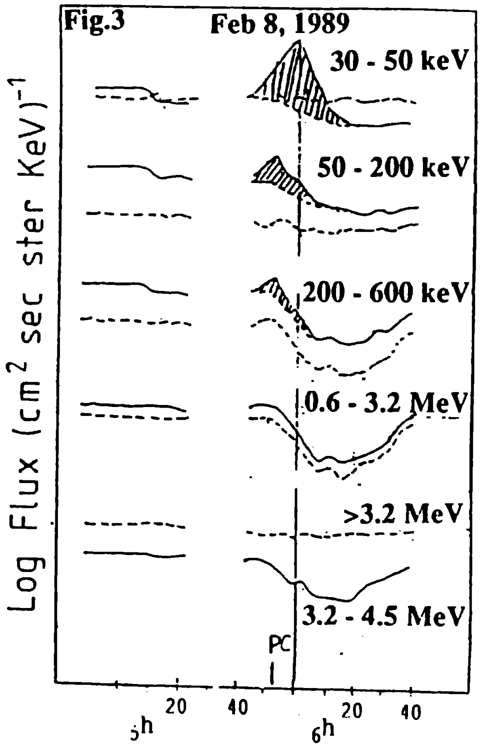
Fig.3
Feb 8, 1989
Log Flux (cm² sec ster KeV)⁻¹
30 - 50 keV
50 - 200 keV
200 - 600 keV
0.6 - 3.2 MeV
>3.2 MeV
3.2 - 4.5 MeV
PC

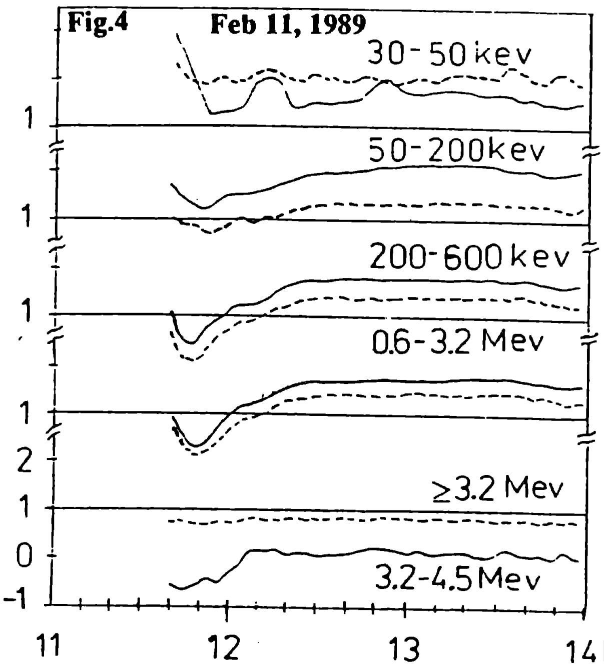
Fig.4
Feb 11, 1989
30-50 kev
50-200kev
200-600kev
0.6-3.2 Mev
≥3.2 Mev
3.2-4.5Mev
11
12
13
14

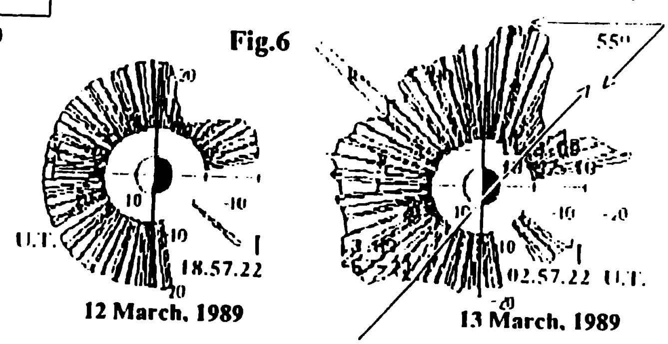
Fig.6
18.57.22
U.T.
12 March, 1989
02.57.22 U.T.
13 March, 1989