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PREPRINT

FIRST RESULTS OF HIGH ENERGY PARTICLE MEASUREMENTS WITH THE TÜNDE-M TELESCOPES ON BOARD THE S/C VEGA-1 AND -2

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ABSTRACT

Short description is given of the VEGA/Halley Missions and the high energy particle experiment performed on it. Intensity profiles of the January 22, 1985 solar particle and ESP events, as observed by the TÜNDE-M instruments, are discussed.

АННОТАЦИЯ

Дается краткое описание научной программы ВЕГА и установленных на КА ВЕГА приборов ТЮНДЕ-М, предназначенных для измерения высокоэнергичных частиц. На основе измерений, проведенных приборами ТЮНДЕ-М, обсуждается временной ход интенсивностей солнечного и высокоэнергичного событий от 22 января 1985 г.

KIVONAT

Röviden ismertetjük a VEGA/Halley missziót, és az űrszondán végzett nagyenergiáju részecskekisérletetet /TÜNDE-M berendezés/. A TÜNDE-M készülékek észlelései alapján tárgyaljuk az 1985. január 22-i nap-részecske és ESP események intenzitásprofiljait.

1. THE VEGA MISSIONS

S/c VEGA-1 and -2 were launched from the Baikonur range on December 15 and 21, 1984, respectively, to a geocentric circular orbit from where, before completing a single orbit, they were directed to orbits leading to the planet Venus, where, gravity assisted by Venus on June 11 and 15, 1985, respectively, they were put onto orbits to meet P/Halley on March 6 and 9, 1986, respectively.

Detailed description of the objectives, instrumentation, orbits, and transmission of information of the two VEGA s/c has been given in [1].

2. THE TÜNDE-M EXPERIMENT

The aim of the TÜNDE-M experiments is to study the high energy (40 to 600 keV) ionic environment of the comet Halley and, in the voyage phase, to observe the heliospheric background of the ionic population of the same energy, as well as to study solar and interplanetary particle acceleration up to energies of 13 MeV/N.

Each VEGA s/c carries a TÜNDE-M instrument. The two TÜNDE-Ms are of identical construction with (nominally) identical parameters. Each TÜNDE-M consists of two particle telescopes (T1 and T2). T1 is viewing at an angle of 55^o to the east ot the sun in the ecliptic plane, the viewing direction of T2 is forming an angle of 90^o to the east of the sun, also in the ecliptic plane. Cross sectional view of a single telescope is given in *Fig. 1*. The geometric factor of a telescope (for particles travelling isotropically along straight lines) is 0.25 cm^2sr. Further details on the construction and functions of the TÜNDE-M instruments are given in [2].

VEGA-1 AND -2
PARTICLE DETECTOR TÜNDE-M

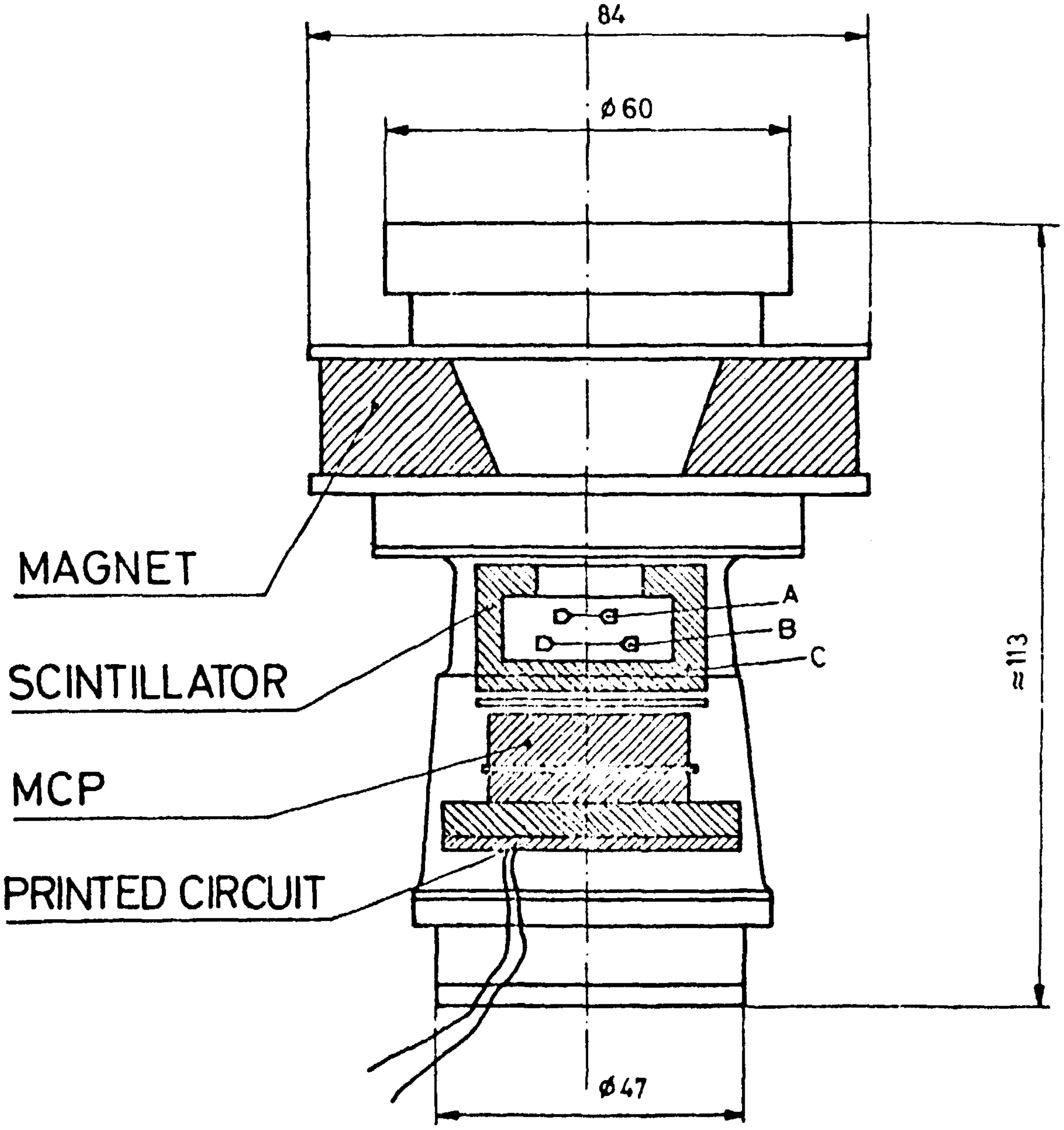

Fig. 1

Schematic cross-sectional view of one of the telescopes of a TÜNDE-M instrument

A silicon detector, 0.1 mm thick, diameter 8 mm
B silicon detector, 1.0 mm thick, diameter 16 mm
MCP multichannel plate

In Table 1, the integration (accumulation) times of the measuring channels are given in the voyage phase (telemetry mode "TR 1"). During the encounter phase, which begins two hours before the closest approach of P/Halley and ends on hour after the closest approach, the total number of channels is 66 (allowing an energy resolution of 10 keV at ionic energies below 490 keV, and 20 keV from 490 keV to 630 keV), and the time resolution of each channel is 4 seconds (telemetry mode "RL"). A third, intermediate, telemetry mode allowing 33 measuring channels with time resolutions of 2.5 min (except of electron and background channels) is also scheduled for about 36 hours preceding the encounter phase (telemetry mode "TR 2").

TABLE 1

Measuring channels and accumulation times of a single telescope on a TÜNDE-M instrument during the cruise phase (telemetry mode "TR 1")

Channel No.	Particles	Energy	Accumulation time [minutes]
1	ions	20-30 keV	10
2	ions	30-40 keV	10
3	ions	40-100 keV	20
4	ions	100-240 keV	20
5	ions	240-630 keV	40
6	ions	630-3000 keV	40
7	protons	3.2-4.5 MeV	10
8	protons	4.5-13 MeV	10
9	$Z \geq 2$ nuclei	3.2-13 MeV/N	40
10	{all nuclei + + electrons	$\geq$13 MeV/N $\gtrsim$ 0.7 MeV}	40
11	electrons	0.16-0.30 MeV	40
12	electrons	0.30-0.70 MeV	10
13	scattered electrons	?	40
14	background of det. A		40
15	background of det. B		40
16	background of det. C		40

Particles counted in channels labelled "protons", "$Z \geq 2$ nuclei", and "electrons" are identified as such by means of coincidence-anticoincidence logical circuits. Particles counted in the "ions" channels are not identified. However, they practically do not contain electrons: low energy electrons ($\lesssim$160 keV) are deflected by the magnets applied to the telescopes (see *Fig. 1*), and electrons with energies above that limit are practically excluded by the anticoincidence signal of the back detector B. See, however, the note in pragraph 4.3 on scattering effects.

In the environment of P/Halley, where the solar wind may pick up cometary ions, there is a possibility to determine masses of the picked up ions in the following way. Theory predicts, and recent experiments [3] have confirmed that the energy spectrum of ions of mass m_i shows a sharp cut off at energies $\frac{1}{2}\, m_i (2w)^s \sin^2\varphi$ where φ is the angle of the solar wind flow and the magnetic field direction, and w is the solar wind velocity. w and φ are measured by plasma-experiments onboard the VEGA s/c. Thus sharp decreases, if they are observed in the ionic spectrum near P/Halley, may be interpreted as the presence of ions with masses m_i where E_i is the

$$m_i = E_i/(2w^2 \sin^2\varphi) ,$$

energy where the ion spectrum shows sharp decrease. The amounts of the sudden spectral decreases themselves may yield the mass spectrum of the picked up cometary ions.

3. PERFORMANCE OF THE TÜNDE-M INSTRUMENTS

TÜNDE-M on VEGA-1 was switched on on December 23, 1984; on VEGA-2, on December 28, 1984. Apart of short periods of attitude and orbital corrections, they were switched on continuously and functioning correctly until the begin of the Venus encounter maeuvres. After the Venus encounter Telescopes 1 of TÜNDE-M, both on VEGA-1 and -2, have failed to answer to switch-on-commands. Telescope 2 on VEGA-1 has functioned well; from time to time there are some failures in the telemetry output of Telescope 2 on VEGA 2.

In the period December 1984 - April 1985, several cases of interplanetary acceleration of charged particles up to MeV energies (including a sequence of corotating events spaced at intervals of ~27 days), and a large solar flare acceleration event were observed by the TÜNDE-M instruments. A short description of the flare particle event is given in what follows.

4. THE SOLAR PARTICLE EVENT OF JANUARY 22, 1985

4.1 There was a 2B flare on the sun at 08° S, 38° W, beginning at 23.50 on January 21, 1985 and ending at 00.43 UT on January 22, 1985. The flare was accompanied by strong radio and X-ray disturbances.

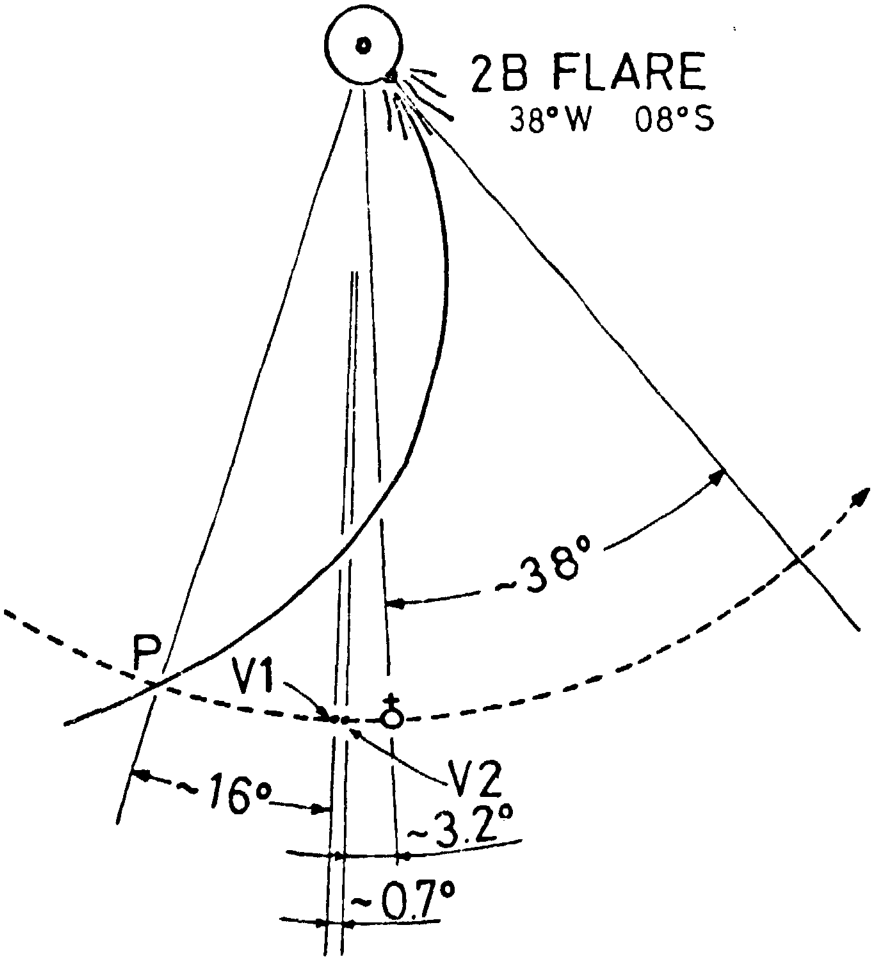

Fig. 2

Relative positions of the sun, earth, and s/c VEGA-1 and -2 on January 22, 1985

P Point of intersection of the flare based interplanetary magnetic field line with the earth's orbit

V1, V2 S/C VEGA-1 and VEGA-2, respectively

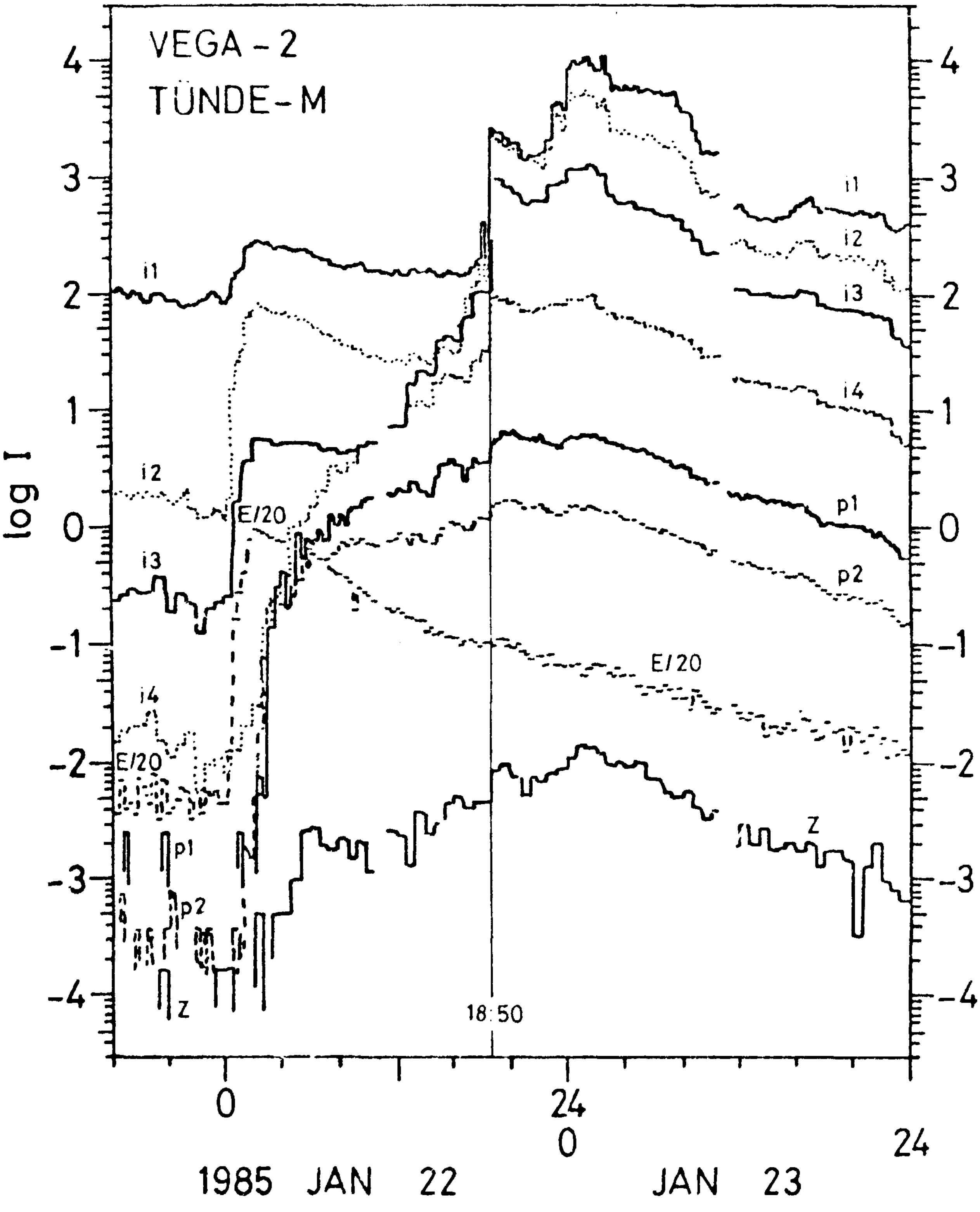

Fig. 3

Intensity profiles of solar flare and ESP particles of various energies observed by Telescope 2 of TÜNDE-M on VEGA-2.

Meanings of the symbols I, i1, i2, i3, i4, p1, p2, E/20, and Z are explained in the text

The relative positions of the sun, earth, and the two VEGA s/c on January 22, 1985 are shown in *Fig. 2*. VEGA-1 and VEGA-2 were at distances of 0.983 AU and 0.987 AU from the sun, respectively, (the earth was at 0.984 AU), and at distances of 0.0375 AU and 0.0352 AU above the ecliptic plane, respectively. The distance of VEGA-2 from the earth was 0.066 AU, the distance of VEGA-1 from VEGA-2 was 0.013 AU.

4.2 *Fig. 3* shows the results as observed in the eight most interesting channels (out of the 16 channels listed in Table 1) by Telescope 2 of TÜNDE-M on VEGA-2, in the period 16^h U.T. January 21 - 24^h U.T. January 23, 1985. The eight channels displayed are the following:

i1 = ions, 40 - 100 keV
i2 = ions, 100 - 240 keV
i3 = ions, 240 - 630 keV
i4 = ions, 630 - 3000 keV

p1 = protons, 3.2 - 4.5 MeV
p2 = protons, 4.5 - 13 MeV
E/20 = electrons 0.3-0.7 MeV
Z = $Z \geq 2$ nuclei 3.2 - 13 MeV/N

The values displayed are those of log I, where

$$I = \frac{C}{G\Delta E}\ [\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{MeV}^{-1}]$$

and

$G = 0.25\ \mathrm{cm}^2\ \mathrm{sr}$ (geometric factor)
ΔE = energy range of the channel in MeV
C = number of particles detected per second ,

except of the channel E/20 (electrons, 0.3-0.7 MeV), where the values displayed are those of log(I/20).

Results obtained by Telescope 1 of the same TÜNDE-M on VEGA-2 are very similar to those shown in *Fig. 3*. The deviations may be explained in terms of the different orientations of the two telescopes.

Results obtained in the electron and identified nucleon channels of TÜNDE-M on VEGA-1 (in both telescopes) also agree well with the values shown in *Fig. 3*. Small deviations which occur may be attributed to differences of magnetic field conditions relating to the two s/c which were at 0.013 AU from each other. The ion channels on VEGA-1, in both telescopes, show, however, rather peculiar profiles which might be difficult to explain in terms of magnetic field conditions. The analysis of the data is going on.

4.3 As it can be seen from *Fig. 3*, the January 22-23, 1985 energetic particle event was a rather complicated one.

Electrons (channel E/20 on *Fig. 3*) show the familiar picture displaying quick arrival (at 00:20 U.T., i.e. some 30 minutes after the time of the X ray burst), short duration of injection period, and a subsequent diffusion type decay of the intensity. Neither of the other profiles shown in *Fig. 3* is, however, easy to interpret.

The simultaneous sudden increases in channels i1, i2 and i3 at 0020 on Jan. 22 may partly be due to electrons scattered in the top silicon detector (detector A in *Fig. 1*) and partly to ions which must have been accelerated by an earlier solar or interplanetary event. This latter hypothesis is substantiated by two observations. First, the ion profiles observed on VEGA-1 (not displayed in *Fig. 3*) show increases starting 2 to 3 hours before the onset of electrons on VEGA-2 (00:20, Jan. 22), they certainly cannot be connected with the solar flare which commenced at 23:52, Jan. 21. VEGA-1 was by 0.7° to the east from the earth (see *Fig. 2*). A particle population with an east-west azimuthal velocity of ~300 km/s would take about two hours to reach VEGA-2 and could thus contribute to the sudden increase of the fluxes observed in the ionic channels of VEGA-2, beginning with 00:20, Jan. 22. Second, the gradual onsets of channels i1 and i4 on VEGA-2 (*Fig. 3*) at about 00:20, Jan. 22, point also toward an ionic contribution.

4.4 A very interesting feature of the profiles in *Fig. 3* is the sharp increase of all intensities (expect that of electrons and 4.5-13 MeV protons) at 18:50 U.T. on January 22. Obviously, a region containing dense high-energy-particle populations reached VEGA-2 from the east. (From the east, since a similar sharp increase was observed in the corresponding VEGA-1 fluxes about 2 hours prior to VEGA-2.) There must have been a strong dividing surface (tangential discontinuity?) confining the dense population to the region limited by that surface. The dense population certainly contained 3.2-4.5 MeV/N protons and heavier nuclei (channels pl and Z in *Fig. 3*). It is difficult to attribute the origin of that population to the 2B flare at 23:52 U.T., Jan. 21. Assuming a rapidly expanding magnetic bubble blown by the flare, radial velocities exceeding 1 AU/18 hours = 2300 km/s ought to be attributed to the discontinuity surface limiting the bubble. Its azimuthal velocity (at 17^h-18^h on Jan. 22) being ~300 km/s would hardly be enough to cover 16° in 18 hours. It seems more probable that the dense population is of interplanetary origin: interplanetary shock or corotating type of acceleration.

The gradual increases preceding the dividing front at 18:50 Jan. 22 show onsets shifting toward earlier hours, and amplitudes increasing with particle energies. To attribute them to flare--accelerated particles, a rather rapid coronal propagation and a practically scatter-free interplanetary propagation must be supposed, otherwise the observed flight times from the flare site to the s/c would not be sufficient to reach the s/c. On the other hand, if the propagation were as supposed, the large delay and flatness of the maxima of the pl, p2, and Z channels could only be explained by a very long lasting (of the order of a day or so) flare injection process - which again would be rather exceptional.

Analysis of these and other features of the event are still in progress. Quantitative results will be published later on.

* * *

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