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THE VEGA PLASMAG-1 EXPERIMENT: DESCRIPTION AND FIRST EXPERIMENTAL RESULTS

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ABSTRACT

The PLASMAG-1 experiment on board the VEGA-1/2 spacecraft designed to explore the solar wind and the cometary plasma environment are described. The first experimental results including the observation of a high-speed stream and the measurements performed simultaneously with the ICE Giacobini-Zinner encounter are discussed.

АННОТАЦИЯ

Описываются установленные на борту КА ВЕГА-1 и ВЕГА-2 приборы ПЛАЗМАГ-1, служащие для изучения солнечного ветра и плазменной обстановки около кометы. Обсуждаются первые экспериментальные результаты, в том числе, результаты наблюдения плазменного потока большой скорости и измерений, проведенных одновременно с измерениями КА ICE в районе хвоста кометы Джакобини-Циннера.

KIVONAT

A VEGA-1/2 ürszondákon elhelyezett, a napszél és az üstökös plazmakörnyezetének vizsgálatára tervezett PLASMAG-1 kisérletet ismertetjük. Beszámolunk az elsõ kisérleti eredményekről, köztük egy nagysebességü plazmanyaláb észleléséről, és az ICE ürszondának a Giacobini-Zinner üstökössel való találkozásával egyidejüleg végzett mérésekről.

In December 1984 two identical spacecraft VEGA-1 and VEGA-2 were launched to the comet P/Halley with Venus flyby. The plasma on board VEGA's is explored by the sensors of the PLASMAG-1 instrument. The scientific goals of the plasma experiment, the approach to their solution and the basic description of operation were published earlier [1,2]. Here, after a short description of the PLASMAG-1 experiment containing some additional information, the schedule of measurements during the cruise phase and some preliminary early results will be presented.

The main parameters of the six independent sensors of the plasma experiment PLASMAG-1 are given in Table 1. Sensors A_o, A_2 and A_3 are oriented along the spacecraft-comet relative velocity vector, sensors A_1 and A_4 are oriented to the Sun, while sensor A_5 is perpendicular to the ecliptic plane.

Sensor A_o, implanted to PLASMAG-1 by SSD ESA consists of two golded plane electrodes, the central probe and the guarding ring is at a potential of -17 V. This sensor was designed to observe neutral gas and dust fluxes in the coma.

The potential at the analysing grid of sensor A_1 which is a Faraday cup can be a/ 0 V, b/ 15 V or c/ 3500 V. The difference between measurements in mode c/ and a/ is proportional to the solar wind ion flux with energies $0\ eV < E < 3500\ eV$. The comparison of measurements in mode b/ and a/ will permit to estimate the effect of secondary ions in the spacecraft vicinity.

In sensor A_2 which is a Faraday cup for observing cometary ions, relatively thick dust resistant diaphragms are used instead of analysing grids. Sensor A_2 has one additional mode of operation compared with sensor A_1. In this mode the usual negative potential of -60 V at the antiphotoelectron diaphragm is replaced by a positive potential of 40 V. In this case the collector current of the Faraday cup is created by secondary electrons from the collector produced by cometary neutrals and dust, therefore A_2 as well as A_0 sensor can observe their fluxes.

The hemispherical electrostatic analysers A_3 and A_4 were designed to observe the energy spectra of cometary and solar wind ions, respectively. To widen the acceptance angle /see Table 1/, quadrupole electrostatic lenses were installed in front of the aperture of the analysers. The energy spectrum is measured in 120 energy intervals for cometary ions and 60 intervals for solar wind ions. The accumulation time of counts in each energy interval is given in Table 2 for the different modes of operation for sensors A_3, A_4 and A_5.

The cylindrical electrostatic analyser A_5 is used for electron energy spectra measurements. The energy range of this sensor is divided into two subranges 3 eV - 100 eV and 0.1 keV - 10 keV, where a different source of deflection voltage is used. Within each energy subrange the electron energy spectrum is measured in 15 energy intervals.

The main mode of operation for PLASMAG-1 during the cruise phase is the Trassa-1 mode. In this mode only two sensors, A_4 and A_5 are operating except for the calibration cycles. Two energy spectra are measured for both solar wind ions and electrons in every 20 minutes. This measurement is completed in about 10 seconds.

After opening the protecting cups of the analysers A_3, A_4 and A_5 and after the continuous outgasing period, the PLASMAG-1 instrument was switched on onboard both VEGA spacecraft on March 5, 1985. Simultaneous operation on board both spacecraft in Trassa-1 mode was continuing to the middle of April when the temperature inside both PLASMAG-1 instruments began increasing and therefore they were switched off. The increase in temperature occurred because the spacecraft were approaching the Sun and relatively large unthermoshielded surfaces were illuminated continuously by the Sun. Onboard VEGA-1 A_3 and A_5 sensors were operating only during the communication session in cometary mode on March 5. There was no scientific information from these sensors later, probably due to the failure of the charge-sensitive CEM amplifiers.

After the Venus flyby, the distance between the Sun and the VEGA spacecraft was increasing and the plasma experiments were switched on July 22-25 in Trassa-1 mode and the instruments were operating to August 8-13. At this time VEGA-1 and VEGA-2 possibly passed the distant magnetotail of Venus and therefore the scientific instruments were switched to the more informative Trassa-2 mode of operation. Since an incomplete set of digital command was sent to PLASMAG-1, the experiment was not operating in Trassa-2 mode.

On September 10 Trassa-2 mode was switched on again to observe the interplanetary space in more details during the ICE encounter with comet Giacobini-Zinner. Data recorded in Trassa-1 mode from the middle of August to Sept 10 were not telemetered. The PLASMAG-1 experiments were operating in Trassa-2 mode on both VEGA spacecraft for a few hours in the beginning of the session, then after some interruptions of unidentified nature, no more information came from the PLASMAG-1 experiment on VEGA-1. The instrument on VEGA-2 was normally operating during the whole communication session.

In the present time /end of November, 1985/, the PLASMAG-1 instrument is switched off onboard VEGA-2 in order to save the resources of the plasma experiment, since September 22 the solar wind ion component has been observed only by VEGA-1 in Trassa-1 mode. It should be mentioned here that during the cruise phase, in addition to the Trassa-1 and Trassa-2 modes there are communication sessions also in cometary mode with both spacecraft under the slow and fast telemetry rates.

Figure 1 shows the energy spectra of the solar wind ion component measured by the A_4 analyser onboard VEGA-2 on March 10, 1985. The spectra presented are plotted in logarithmic scale. During the whole period, distinctly separated H^+ and He^{++} maxima can be observed. For some periods a third maximum of higher energy is observable, probably produced by O^{6+} ions. The interesting peculiarity of the data presented in Figure 1 is that for about 6 hours from 9 UT up to 15 UT a significant expansion of solar wind spectra /which corresponds to temperature enhancement/ was observed under practically unchanged solar wind velocity /see the energy of most abundant ions in Fig. 1/. At the present time we do not know any publications distinguishing and analysing similar events in solar wind plasma.

The estimated hydrodynamical parameters - bulk velocity, temperature and density - are presented in Fig. 2 for on extended time interval compared to the one on Figure 1. Dots show data from VEGA-1 and continuous lines present the data from VEGA-2. These parameters were estimated supposing a Maxwellian distribution for protons and using a limited number of experimental points close to the H^+ maximum. The results of A_4 calibration with monoenergetic ion fluxes /performed on the MPAE, Lindau facility/ and the results of comparison of A_4 readings with simultaneous Faraday cup A_1 readings in the solar wind were used for the calculations. Some minor changes in the parameters in Figure 2 probably originate from the instability of the simple computer code applied.

As seen from the data shown in Figure 2, the values of bulk velocity, density and temperature of protons measured onboard of the VEGA-1 and VEGA-2 spacecraft are in reasonable agreement with the exception of significantly different densities estimated from VEGA-1 and VEGA-2 data between 18 UT and 24 UT on March 10. /The reasons of this difference, possibly connected with a spatial nonuniformity in the solar wind, should be thoroughly analysed and will not be further discussed here/. The expansion of solar wind spectra observed from 9 UT to 15 UT /Fig. 1/ corresponds to an increase of proton temperature T_p by a factor of about 6-8 from $\sim 5 \cdot 10^4$K up to $\sim 3\text{-}4 \cdot 10^5$ K while solar wind velocity V_p varied unsignificantly decreasing from $\sim$460 km/sec to $\sim$420 km/sec. For an interpretation of such a considerable local increase of the solar wind internal energy we should find the source of this energy. Only one of the possible explanations of this rather unusual observation will be discussed here.

As one can see from Fig. 2, proton density n_p is increasing just before and after the region with enhanced proton temperature. Regions with enhanced n_p in the solar wind are usually formed as a result of dynamical compression of low speed plasma by a high speed solar wind stream as well as in the vicinity of a heliospheric current sheet /NCDE/ [3,4]. These enhanced n_p regions are often overlapping. Figure 3 shows the estimated V_p, T_p and n_p parameters for a solar wind high speed stream which was observed onboard VEGA-1,2 from April 1 to April 6. The V_p, T_p and n_p variations are typical for an isolated high speed stream event therefore no detailed discussion will be given here. Similar high speed streams were observed during the declining phase of the previous 20th solar cycle [5,6] and also earlier in the declining phase of the 21st cycle [7].

As we can see from Figure 3 and as of course well known from observations of multiple solar wind high speed streams /see e.g. [4]/, the n_p maximum values are observed before solar wind velocity V_p is increasing and a significant T_p

enhancement followed n_p maximum just before the beginning of the increase in V_p. Similar variations in n_p and T_p /but not in V_p/ were observed at the leading edge of the "hot" solar wind region from 8 UT to 10 UT on March 10, 1985 /Figure 2/. The n_p and T_p variations occur in reverse order between 12 UT and 17 UT when the spacecraft are leaving the "hot" regions. So we can suppose that VEGA-1,2 spacecraft were approaching a solar wind high speed stream on March 10, 1985 and passed in the vicinity of it measuring n_p and T_p enhancements but no increase in V_p.

Such an event could occur in the vicinity of a heliospheric current sheet if the spacecraft intersect this formation twice. In such a case the region with enhanced n_p at 8-10 UT /Figure 2/ could be produced by the overlaping of the high density region in the vicinity of the heliospheric current sheet and that of at the leading edge of a hypothetical high speed stream /the increasing of V_p in this stream was not observed/. The second region with the enhanced n_p between 12-17 UT is naturally interpreted as a result of the second intersection of the current sheet by the spacecraft.

A preliminary comparison of plasma data with the results of simultaneous magnetic field measurements by MISHA magnetometer /E. Eroshenko, K. Schwingenschuh, private communication/ does not contradict to the possibility that both spacecraft intersected a heliospheric current sheet during time interval discussed. In order to find sufficient evidences in favour or against the interpretation proposed above, a detailed joint analysis of all sensors of PLASMAG-1 data together with the MISHA magnetic field data is necessary. In case the proposed interpretation is right, the energy source providing high T_p values in the time interval 9-15 UT is the dynamical compression of low speed plasma by a high speed solar wind stream.

Further the results of solar wind measurements in Trassa-2 mode on September 10-11 will be presented here. In this mode of operation 7 energy spectra of solar wind ions are measured in every 20 minutes. The accumulation time of counts is significantly longer than in Trassa-1 mode /see Table 2/. As mentioned above, the September 10-11 period of Trassa-2 measurements include the time interval of ICE encounter with the comet Giacobini-Zinner. On the basis of the estimations by J.Simpson and D. Rabinowitz /private communication/ computations were done in order to find possible dust particles at a minor comet or meteoroid stream on Sept. 10-11 since the VEGA spacecraft were located in the neighbourhood of the Leonid meteoroid stream trajectory.

Figure 4 presents the results of solar wind measurements during Trassa-2 mode of operation on September 10-11, 1985, to support the interpretation of ICE data and dust experiments. As we can see from the data shown on Figure 4 from 9 UT September 10 to 22 UT September 11 - the bulk velocity of solar wind protons was very low and changed between 260 and 280 km/sec. The proton temperature was also low and changed between 20×10^3 and 60×10^3K. In this period VEGA-2 was located about 60^o west of ICE and approximately at 1 AU.

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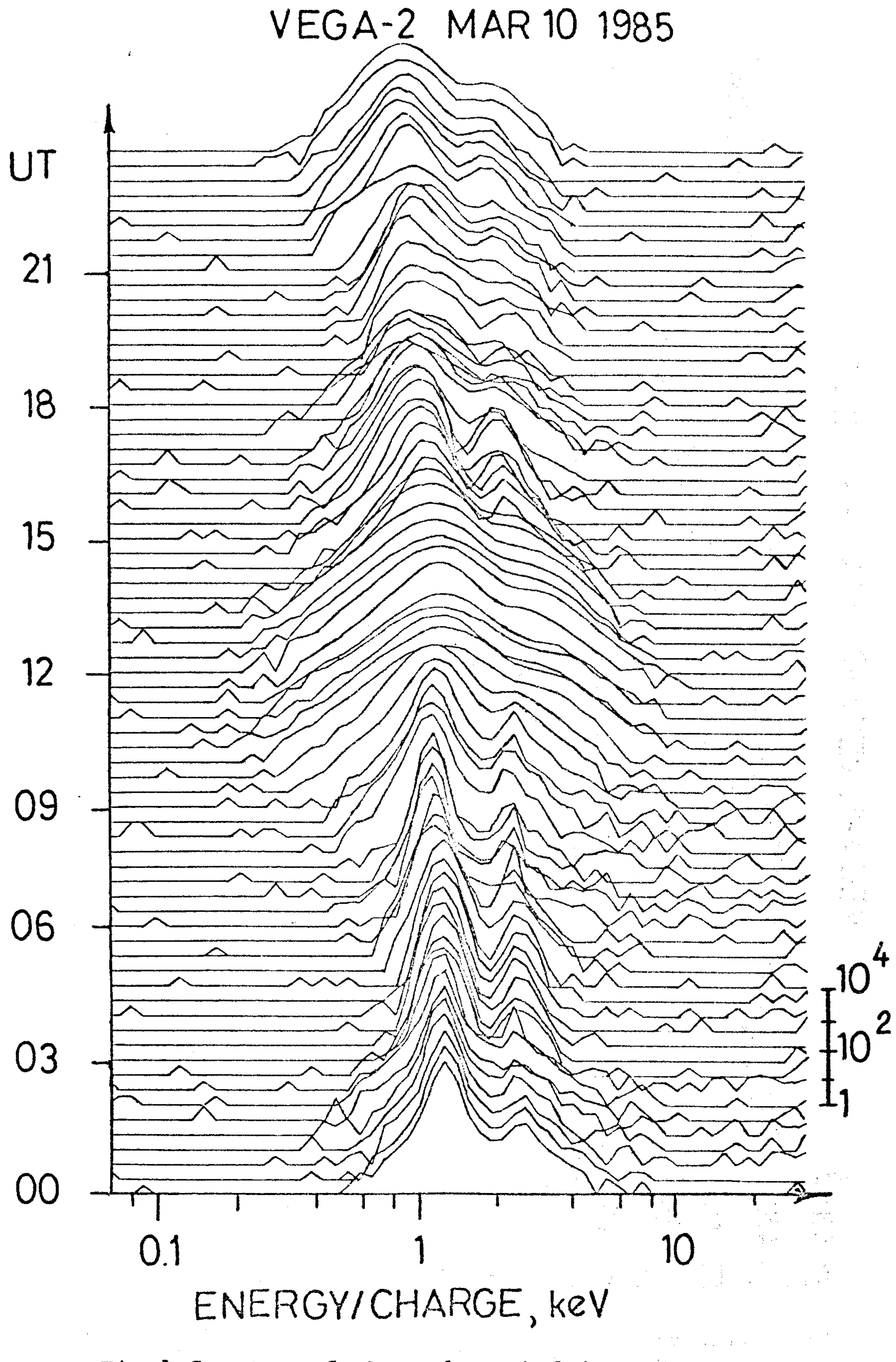

Fig.1 Spectra of the solar wind ion component as measured by the PLASMAG-1 experiment onboard VEGA-2 on March 10, 1985

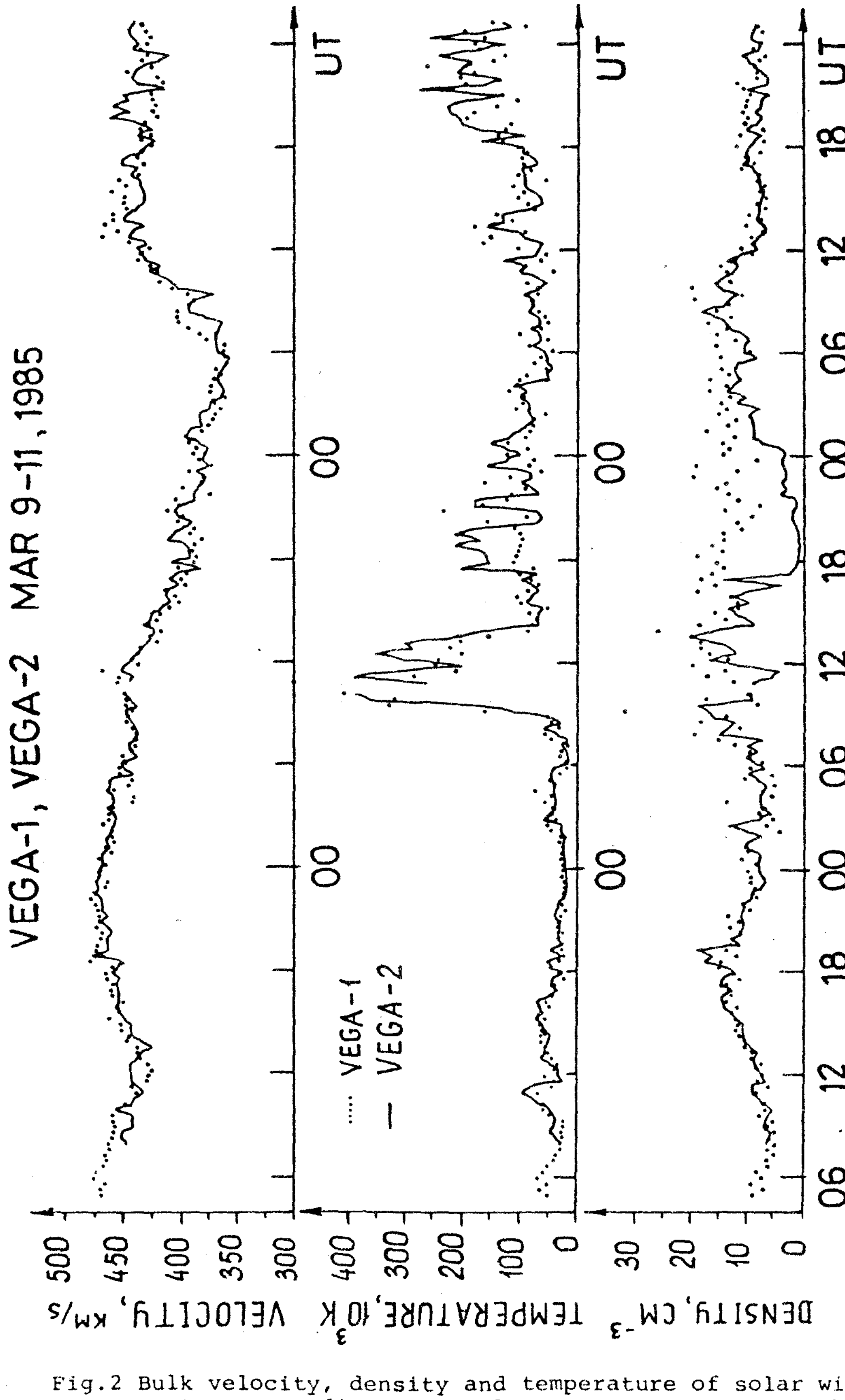

Fig.2 Bulk velocity, density and temperature of solar wind protons according to simultaneous measurements onboard VEGA-1 and VEGA-2 for March 9-11, 1985

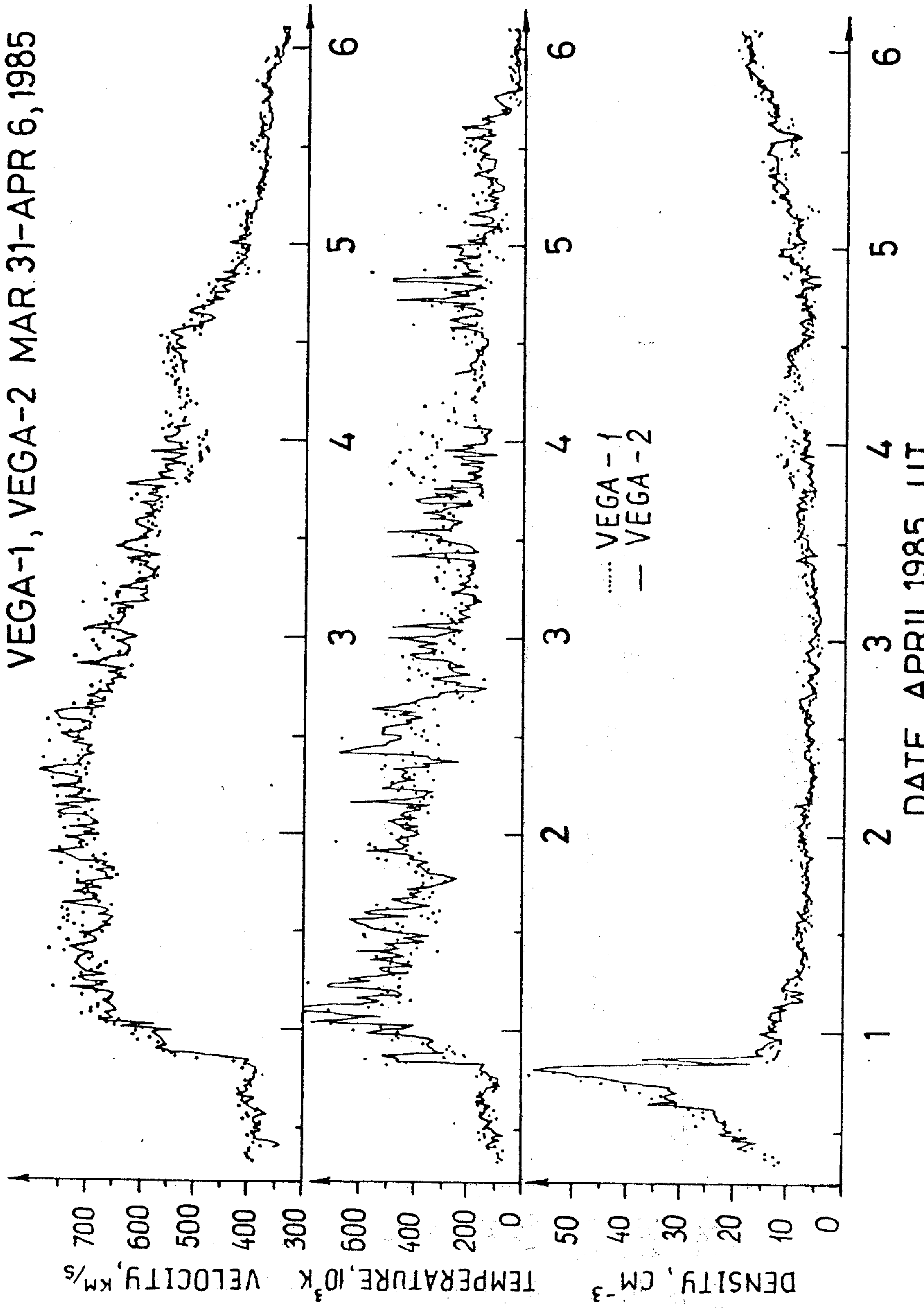

Fig. 3 The same parameters as on Figure 2 for solar wind high speed stream observed onboard VEGA-1,2 on April 1-6, 1985

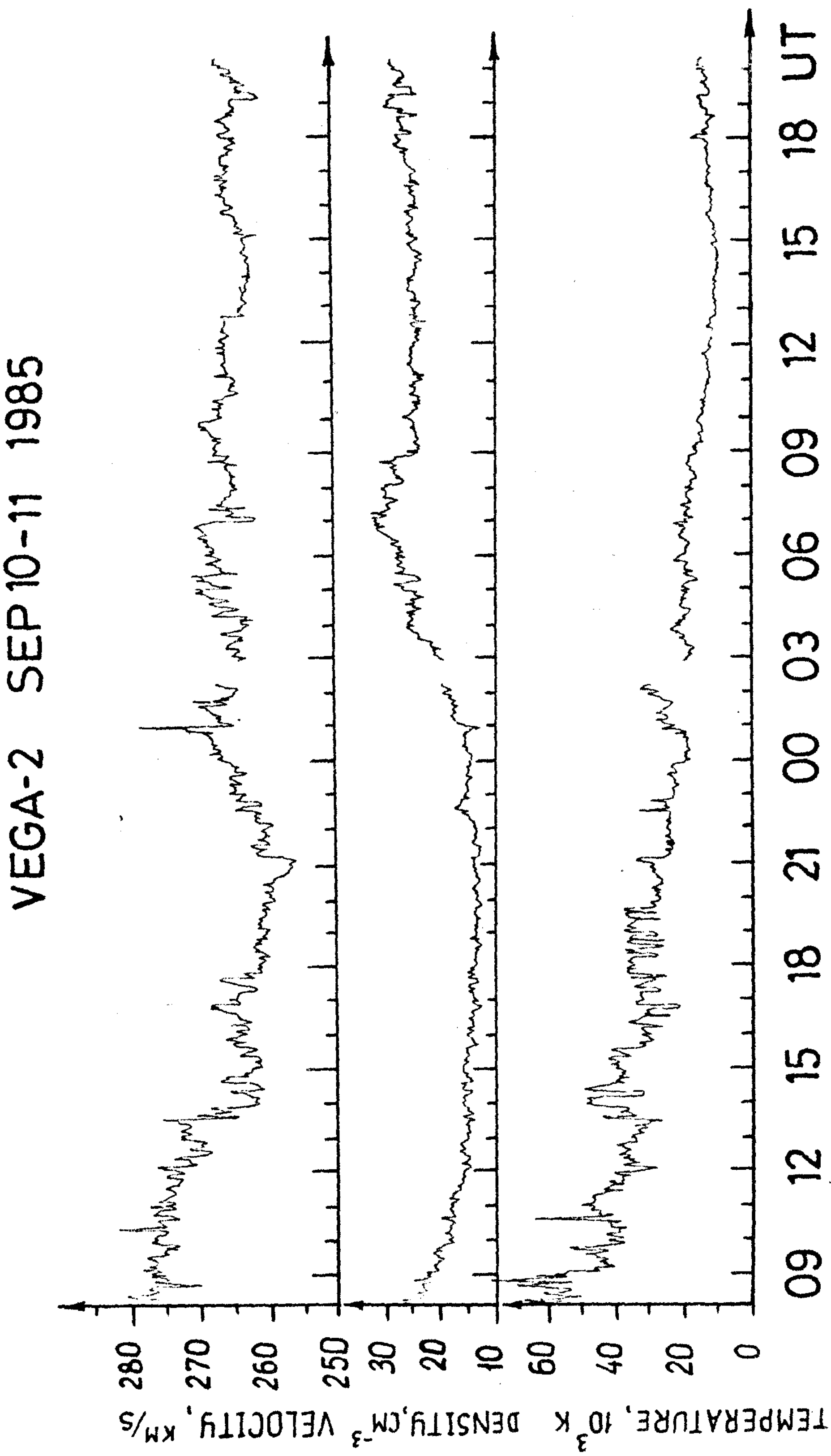

Fig. 4 Estimated solar wind parameters according to VEGA-2 PLASMAG-1 data measured simultaneously with ICE Giacobini-Zinner encounter

Table 1
Parameters of the sensors of PLASMAG-1

Parameter	SENSOR					
	A_0	A_1	A_2	A_3	A_4	A_5
Effective aperture	1 cm^2	1.60 cm^2	0.93 cm^2	$1.4 \cdot 10^{-2}$ cm^2	$4.6 \cdot 10^{-3}$ cm^2	$3.6 \cdot 10^{-3}$ cm^2
Energy range	—	> 0,15,3500 eV	> 0,15,3500 eV	15-3500 eV	0.05-25 keV	0.003-10 keV
Energy gain	—	1	1	8.2	8.2	9.3-10.3
Energy resolution, $\frac{\Delta E}{E}$)*	—	—	—	5.5%	5.6%	7.5%
Angle of acceptance*)	$168^0 \times 168^0$	$84^0 \times 84^0$	$25^0 \times 25^0$	$14^0 \times 32^0$	$38^0 \times 30^0$	$7^0 \times 7^0$

* Full width at 0.1 of maxima

Table 2
Accumulation time of the electrostatic analysers of PLASMAG-1 in different modes of operation

MODE	SENSOR		
	A_3	A_4	A_5
TRASSA-1	—	0.08 s	0.16 s
TRASSA-2	1.3 s	1.3 s	5.2 s
COMETARY	0.005 s	0.005 s	0.020 s

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