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Cosmic Ray Measurements on Board Helios 1 from December 1974 to September 1975: Quiet Time Spectra, Radial Gradients, and Solar Events*

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Abstract. The University of Kiel cosmic ray experiment on board Helios 1 measures nucleons above 1.7 MeV/nucleon and electrons above 0.3 MeV in the inner solar system between 1.0 and 0.3 AU from the sun. A first survey is given on quiet time proton and Helium spectra which are compared near earth and close to perihelion. The anomalous Helium component is also present at radial distances within 0.4 AU. Quiet time Helium spectra from 3.8 to 48 MeV/nucleon gradually increase between December 1974 and June 1975. For the integral radial gradient (protons above 51 MeV) we estimate a value of (11 ± 2.5) %/AU during a period of slowly increasing cosmic ray intensity.

We discuss solar particle events on January 5 (at 0.93 AU), March 7 (at 0.41 AU), and March 19, 1975 (at 0.32 AU). The March 19 event was measured closer to the sun than any other event before. It exhibits sharp temporal structures, differences in the time profiles of various particle species, and a large abundance of Helium 3, with a $^3He/^4He$ ratio of 2 to 3 in the range 5 to 7 MeV/nucleon. This event occurred close to the peak of a high speed solar wind stream.

Key words: Cosmic rays – Quiet time energy spectra – Radial gradients – Solar events – ^3He-rich events.

1. Introduction

The solar probe Helios 1 was launched successfully into a heliocentric orbit on December 10, 1974. It reached its first perihelion at a distance of 0.31 AU from the sun on March 15, 1975. For the first time a fully equipped "particles and fields" instrumentation probed a region that close to the sun. Figure 1

* Dedicated to Professor Dr. Erich Bagge with best wishes for his 65th anniversary

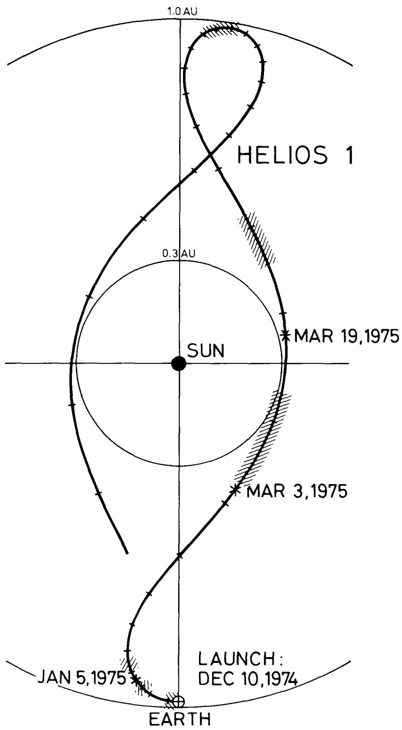

Fig. 1. Helios 1 orbit in a coordinate system with a fixed earth-sun line from December 10, 1974 through September 1975. The perihelion distance is 0.31 AU. Time tags indicate every 10th day of the year. Shaded parts of the orbit represent quiet times outside 0.87 AU or inside 0.47 AU. The positions of the space probe during the solar particle events under discussion are marked too

shows the Helios 1 orbit for the first 10 months of operation in a coordinate system with the earth-sun line fixed.

The University of Kiel experiment on board Helios is capable to measure protons and heavier nuclei above 1.7 MeV/nucleon and electrons above 0.3 MeV. It is designed to study the low intensity galactic cosmic radiation with good energy and charge resolution; for intense solar events we obtain in addition good temporal resolution and measurement of the angular distribution using eight sectors. Isotopes of hydrogen and Helium can be separated.

It is the purpose of this paper to give a first overview of results obtained during the first part of the Helios 1 mission (December 1974–September 1975). This time period is characterized by a general decrease of solar activity towards solar minimum which occurred in July 1976. These relatively quiet conditions facilitate the separation of the gradually varying galactic cosmic radiation from superimposed events of different nature. After a brief description of the instrumentation in section 2 we present in section 3 the temporal variation of selected instrument channels during the above time period.

Long term variations in the integral proton channel (protons above 51 MeV) are partly due to a generally increasing cosmic ray density throughout the whole inner solar system. Nevertheless it is possible to obtain a preliminary estimate for a finite positive radial gradient during this period of decreasing solar activity.

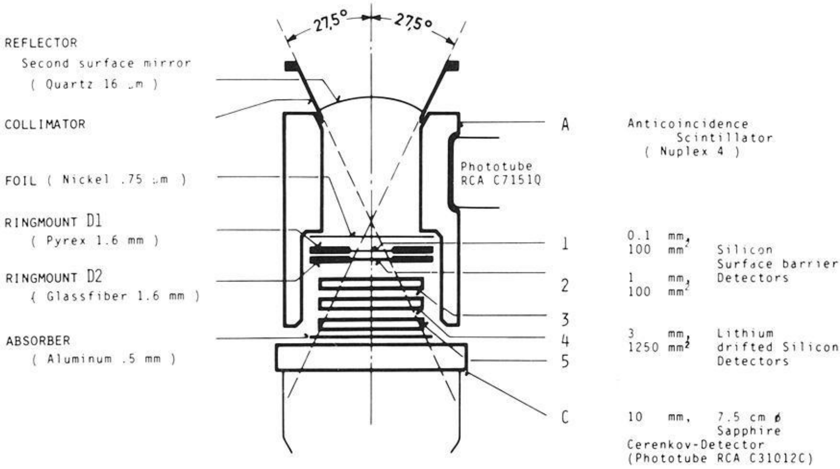

Fig. 2. Cross section of the detector telescope

Quiet time spectra for low energy protons and Helium nuclei as observed near the earth and inside 0.4 AU are compared in section 4. In section 5 we discuss three solar events during the "prime mission" until April 1975. Two of these events occurred when Helios 1 was at 0.41 and 0.32 AU, respectively. The latter event is of particular interest because of its high Helium 3 content and its temporal fine structure. Here we take advantage of the close approach to the sun: it allows a better resolution of small solar events from the galactic background and, in addition, we can study details of the solar injection process which are smeared out for observations at 1 AU due to interplanetary propagation effects.

2. Instrumentation

The detector telescope of the cosmic ray experiment is shown in a cross section in Figure 2. It consists of five semiconductor detectors "1" through "5", one sapphire Cerenkov detector "C", and an anticoincidence scintillator "A" surrounding the detector stack. This configuration has a full opening angle of 55° and geometric factors of 0.48 cm^2sr for nuclei below 51 MeV/N and 2.23 cm^2sr for nuclei above 51 MeV/N. The lower energy thresholds of the instrument are 1.3 MeV for protons, 1.7 MeV/N for heavier nuclei, and $\sim$0.3 MeV for electrons.

Coarse energy ranges are defined by the thickness of detectors and absorbers. Protons are distinguished from heavier nuclei by their different energy loss in the penetrated detectors. Electrons are identified by the fact that contrary to nuclei they pass the first thin detector without triggering it.

Each particle is counted in one of 87 different counters with respect to its energy range, species (electron, proton or $Z \geqq 2$-nucleus) and direction of incidence.

A statistical sample of these particles is further analysed. The pulse heights of the last three penetrated detectors are digitized by logarithmic analog-to-digital converters with a resolution of 8 bits. This allows

- better energy resolution
- separation of isotopes
- measurement of the relative abundances of particles with $Z \geqq 2$
- background reduction

Further details of the instrument are given by Kunow et al. (1975) and by Green at al. (1970).

3. Intensity Time Profiles and Preliminary Radial Gradients

Let us start with a survey over the first part of the mission by presenting daily intensity averages of selected experiment channels. This allows the selection of quiet times for construction of energy spectra (section 4) and gives a first insight into possible radial and temporal variations. In Figure 3 we show the time variations in some energy ranges for electrons (E), protons (P), and $Z \geqq 2$ nuclei (A), which consist mainly of alpha particles. Each curve is denoted by the corresponding particle species and energy window (e.g. A 2–4 stands for alpha particles between 2 and 4 MeV/N). Daily intensity averages are plotted for the first ten months of the mission corresponding to 1.5 orbits of Helios 1. There are time tags for perihelion and aphelion.

Channel P 13–27 indicates the very low level of solar activity during this time. Only a few solar events concentrated in December/January and July/August generated particles with energies above 13 MeV/N.

In the energy range below 13 MeV/N several additional intensity increases occurred due to corotating streams (e.g. in February) or minor solar activity (e.g. in March). The small event shortly after perihelion is of special interest because of its unusually high abundance of ^{3}He. This event together with the events on January 5 and March 3 will be discussed in section 5.

The time profiles of the alpha particles show a behaviour similar to those of the protons. Note, however, that channels A 2–4 and A 4–13 display much less fluctuations than the corresponding proton channels P 1–4 and P 4–13. This can be explained by a higher non solar background, in particular the slowly varying "anomalous Helium component" which might mask fluctuations of the solar Helium component.

In Figure 3 we have also plotted on an expanded linear scale the integral intensity of protons above 51 MeV ($P > 51$). The limitations of using counting rate information only (instead of individual particle identification) are well-known, but we wish to draw some preliminary conclusions from the behaviour of this channel, representing a mean energy of about 1 GeV. Its striking feature is the relatively constant level between December and March, when Helios 1 travelled from 1 AU to 0.3 AU, followed by an increase between March and June, when the space probe returned to 1 AU, and a subsequent slow decrease between June and September during the second approach to the sun.

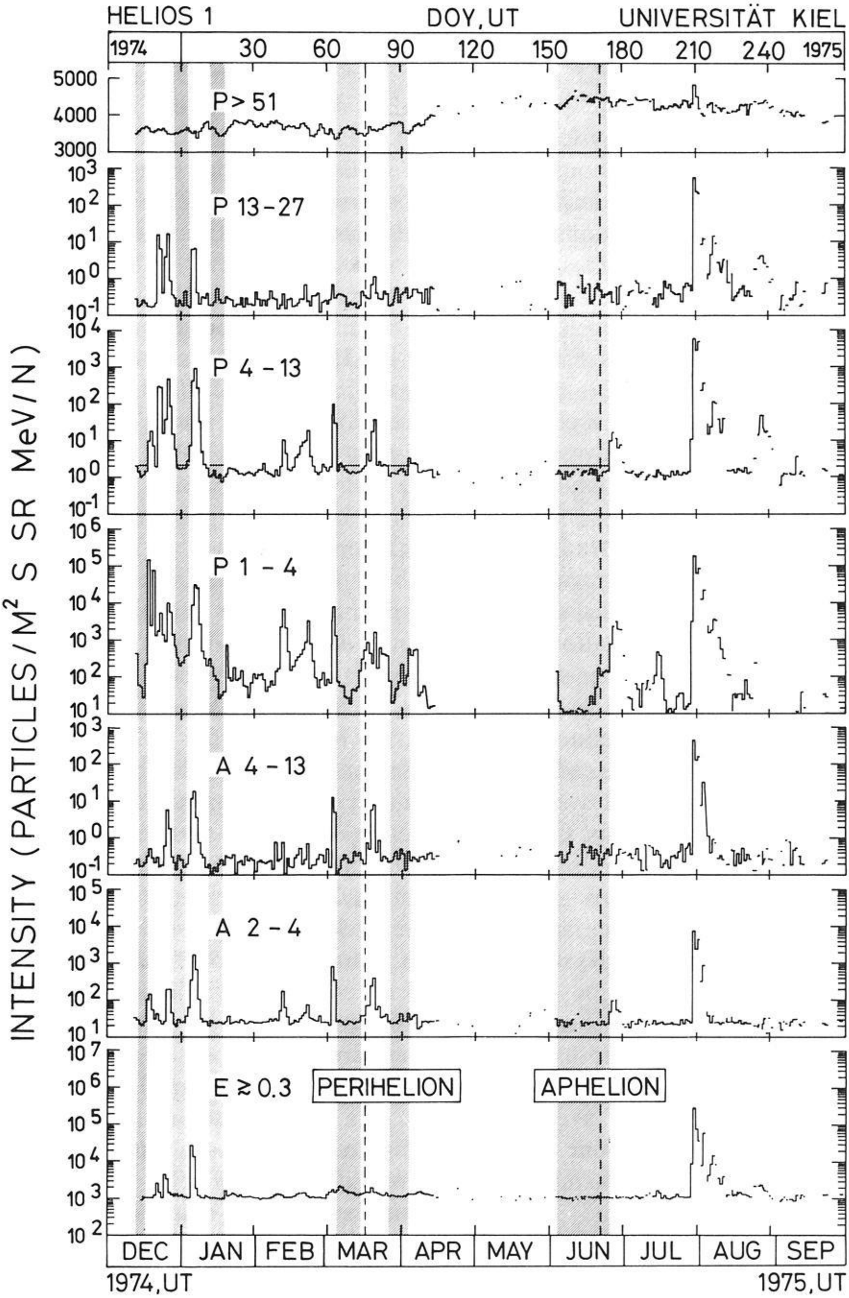

Fig. 3. Daily intensity averages as measured with Helios 1 between December 10, 1974 and September 30, 1975. The different panels show protons (P) between 1 and 4, 4 and 13, 13 and 27, and above 51 MeV, $Z \geqq 2$ nuclei (A) between 2 and 4, and 4 and 13 MeV/N, and electrons (E) above ~ 0.3 MeV respectively. Shaded areas indicate those quiet times for which energy spectra have been derived

The interpretation of this behaviour requires a careful separation of temporal and spatial variations.

In the following we restrict ourselves to the period from December 1974 to June 1975. Inspection of neutron monitor data at Kiel (courtesy O. Binder) and Deep River (Solar-geophysical Data, 1975) shows a gradual increase during this period with a relatively constant slope of $0.50 \pm 0.04\%$ per month for the Deep River data, corresponding to a total increase of $2.7 \pm 0.4\%$ for the full period. There are no indications of severe disturbances of the interplanetary medium.

We performed a regression analysis of the intensity in channel $P > 51$ versus the counting rate of the Deep River neutron monitor for December, January, May and June, when Helios 1 was close to 1 AU. This yields a correlation coefficient of about 0.9 and a ratio of 6.1 ± 0.4 of the fractional change in channel $P > 51$ to the fractional change of the neutron monitor rate. The neutron monitor increase quoted above is then consistent with the $\sim 17\%$ change in channel $P > 51$ between launch to the next aphelion, when Helios was close to 1 AU.

Let us now discuss the radial variation. From launch to perihelion the intensity in channel $P > 51$ varies only by about 1% whereas we see almost the full excursion during the subsequent outward motion. This variation implies that temporal and radial variations roughly cancel each other during the inward motion and add to one another on the outbound pass. This leads to a numerical value for the integral radial gradient of $11 \pm 2.5\%/\mathrm{AU}$ in the radial interval 0.3–1.0 AU. Previously, a value of 5%/AU has been reported from Pioneer 10/11 for the integral radial gradient (Teegarden et al., 1973; McKibben, 1975). The larger value obtained above from Helios may have a number of different reasons: (1) Latitudinal effects. Close to perihelion one has to take into account possible variations with heliographic latitude. Helios changes its position with respect to solar latitude from $-6°$ to $+6°$ within 20 days, and the solar wind measurements show a large latitudinal effect related to coronal structures (Schwenn et al., 1976). (2) Hysteresis effects. Our conclusion that we see a radial gradient effect superimposed on long-term temporal variations was based on a regression analysis in comparison with neutron monitor data, for time periods when Helios was close to 1 AU. Here we ignore possible hysteresis effects between various energies ($\simeq 1$ GeV for the Helios integral channel as compared to the several GeV average response of a high latitude neutron monitor). A sudden jump from one regression line to another in a time span of several weeks (Stoker, and Carmichael, 1971) would lead to different time variations at different energies. (3) Transient modulation. For a given phase in the solar cycle, the experimentally determined gradients are not constant, but vary with time and distance (see McKibben, 1975). Our value of 11%/AU has been obtained by averaging over a limited time period and over a radial distance of ~ 0.7 AU. It may therefore differ from long-term averages over a larger radial distance. It has been noted in particular that larger-than-average gradients are observed during periods of increasing galactic cosmic ray intensity (McKibben et al., 1975). This behaviour is expected qualitatively, if non-stationary solutions of the diffusion-convection model are considered (O'Gallagher, private communication).

Further studies (see section 6) will show which of the explanations are appropriate.

4. Quiet Time Energy Spectra

In this part the energy spectra of protons and Helium nuclei during quiet times at different solar distances will be discussed. Quiet times are defined as those times when the intensity in the 4 to 13 MeV – proton channel does not exceed 2 counts $(m^2 s\ sr\ MeV)^{-1}$. This level is indicated in curve P 4–13 of Figure 3. In order to see radial gradient effects data were taken only, when Helios was outside 0.87 AU from the sun (datasets aphelion 0 and aphelion 1) or inside 0.47 AU (perihelion). The resulting time periods are indicated by shaded areas in Figures 1 and 3, and are given together with the amount of data included in these datasets in Table 1.

During quiet times a very high percentage (about 95%) of the counted particles can be pulse height analysed. Thus the background in each count rate channel, partly due to particles traversing the telescope from the backward direction, can be accurately identified by a 2- or 3-dimensional pulse height analysis. A normalization to absolute intensities can be easily performed with the respective count rate.

The proton spectra for these three time periods are shown in Figure 4a. The intensities above 30 MeV increase with time by roughly 25%. For the lowest energy channel, however, the trend is reversed. Thus for the time periods which were defined (somewhat arbitrarily) as "quiet", the lowest energy protons apparently decrease with decreasing solar activity; this might indicate a residual effect of protons of solar origin.

The energy spectra of Helium nuclei (Figure 4b) show a more regular pattern. In all cases the spectrum is relatively flat in the energy range 3.7 to 48 MeV/N with no low energy turn up, showing the features of the "anomalous" Helium component (Garcia-Munoz et al., 1973, see also Hovestadt et al., 1973, McDonald et al., 1974).

A superposition of the proton and Helium spectra at perihelion is shown in Figure 4c. In the energy range from 10 to 40 MeV/N the Helium intensities are well above the proton intensities by a factor of about 2 at 20 MeV/N.

Table 1. Periods of quiet times, used for evaluation of the energy spectra

Dataset	Radial distance of Helios (AU)	Period	Quiet time data (h)
aphelion 0	0.98 to 0.87	74 Dec 13, 2–74 Dec 17,2 74 Dec 28, 2–75 Jan 2,23 75 Jan 11,12–75 Jan 17,23	296
perihelion	0.31 to 0.47	75 Mar 4,12–75 Mar 14,23 75 Mar 26, 0–75 Apr 2,0	348
aphelion 1	0.98 to 0.96	75 Jun 2, 0–75 Jun 24, 0	262

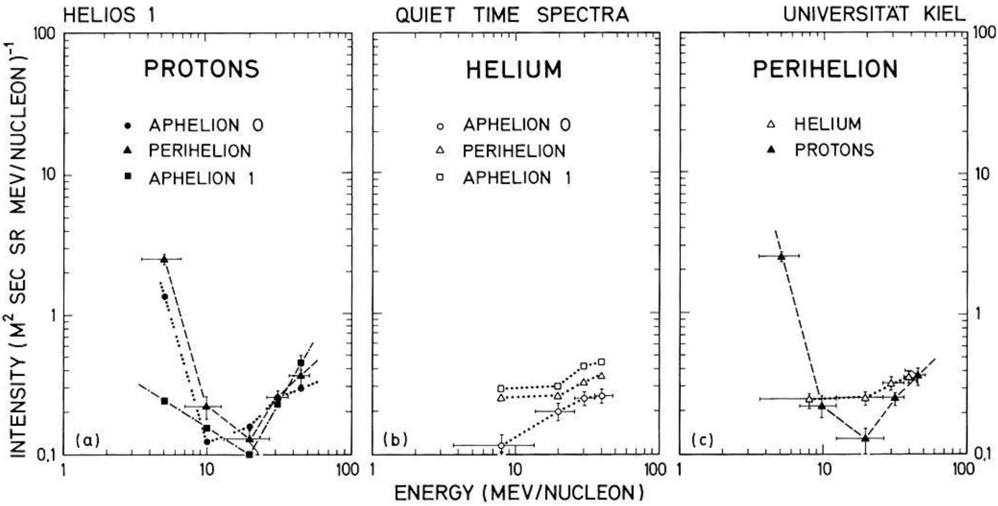

Fig. 4a–c. Quiet time spectra of protons and Helium nuclei during different time periods close to aphelion 0 (>0.87 AU), perihelion (<0.47 AU), and aphelion 1 (>0.96 AU) (see Table 1 and Fig. 1 and 3). **a** Proton spectra near aphelion 0 (December 1974/January 1975), perihelion (March/April 1975), and aphelion 1 (June 1975). **b** Helium spectra near aphelion 0, perihelion and aphelion 1. **c** Proton and Helium spectrum at perihelion. Error bars and energy intervals indicated at one spectrum only are typical also for the other spectra

This confirms the presence of the anomalous Helium component also in the vicinity of the sun between 0.4 and 0.3 AU.

Let us draw some preliminary conclusions from the data presented in Figure 4b. In the integrated Helium intensity in the energy range 13 to 47 MeV/nucleon we find a relative increase of $24 \pm 18\%$ from Dec 74/Jan 75 to March 1975, and a relative increase of $26 \pm 8\%$ from March to June 1975. This means that in contrast to the behaviour of the high energy protons discussed in the preceding section there is no significant difference between the inward and outward motion of Helios. Therefore, the influence of a possible radial gradient is small. This is in agreement with the small gradients reported beyond 1 AU from the Pioneer 10/11 missions (10%/AU between 10 and 19 MeV/nucleon according to McKibben et al. (1975); 12%/AU between 8.8 and 23.5 MeV/nucleon according to Webber et al. (1975)). Converting these values to a radial separation of 0.7 AU, we would expect an effect of the order 7–8% variation between 1.0 and 0.3 AU, which would indeed be unresolvable from the above temporal variation within the statistical uncertainties. According to Garcia-Munoz et al. (1975) the first "flat" Helium spectrum was observed to occur first in 1972, and the Helium intensity below about 80 MeV/nucleon was significantly higher than 1971. Time variations in this anomalous component between 1972 and 1974 are less pronounced. Comparison of published measurements (Garcia-Munoz et al., 1973, 1975; Christon et al., 1975; Mewaldt et al., 1975a, 1975b; Zamov, 1975) shows that there exist discrepancies between results from different instruments on different spacecraft. Part of these discrepancies may be due to different criteria in the selection of "quiet times". However, combination of the available measurements reveals a trend of a general intensity increase between 1972 and 1974. This trend is clearly continued in the 13 to 47 MeV/nucleon Helium data from Helios between December 1974 and June 1975.

Fisk et al. (1974) have proposed that the anomalous composition of low energy cosmic rays be caused by interstellar neutral particles which enter the solar cavity and are ionized here. In a model developed by Fisk (1976a) these ions with energies in the keV/nucleon range are accelerated by the solar wind to tens of MeV/nucleon. Fisk (1976b) compares the consequences of this model with a direct galactic origin of the anomalous component. His conclusion is that for an origin by interplanetary acceleration the modulation of these particles can be understood in the context of present modulation theory, whereas the galactic origin would require a considerable modification of the present cosmic ray diffusion scheme in the interplanetary medium.

Klecker (1977) has summarized the arguments in favor of an interplanetary origin for the anomalous component. His model calculations reproduce the 1973 quiet time data for Helium nuclei above 10 MeV/nucleon reported by Garcia-Munoz et al. (1975). It will be further studied whether the temporal variations seen on Helios can be related simply to a change of the modulation parameter, or whether changes in the acceleration rate (Fisk, 1976a) are also involved. In principle, the modulation *and* the acceleration rate should be variable with the solar cycle. Both parameters are contained in present models for the anomalous component (Fisk, 1976a, 1976b; Klecker, 1977).

5. Solar Particle Events

In the previous section we discussed measurements during solar quiet times of the Helios 1 prime mission. These times are marked by shaded columns in Figure 3. Several solar events occurred during the remaining intervals. The three events on January 5, March 3, and March 19, 1975, will be discussed in more detail because they represent examples of solar events with very different characteristics. At the time of the three events Helios was at radial distances of about 0.93, 0.41, and 0.32 AU, respectively.

Figure 5 shows in the upper panel the constellation of Helios with respect to sun and earth in the ecliptic plane for the three events. Black dots on the solar surface mark the position of active regions. The spiral lines indicate the ideal interplanetary magnetic field. The lower panel of Figure 5 sketches the intensity time profiles of the events for 4–13 MeV protons. Note that all three profiles are presented on the same time scale.

January 5, 1976, Event

On January 5, 1975, Helios was at a solar distance of 0.93 AU and 7° east of the earth. Two active centers were located nearly 180° apart in solar longitude, roughly symmetric to the Helios connection longitude (see Fig. 5). Both active centers had the capability to accelerate particles.

Green et al. (1975) have performed a preliminary analysis of this event by

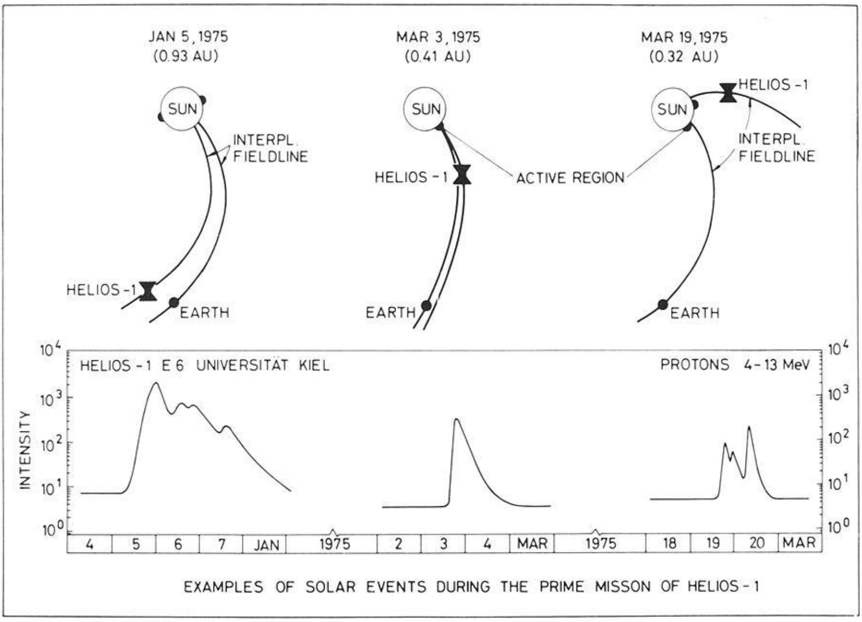

Fig. 5. Smoothed time profiles of 4 to 13 MeV protons during selected solar events, observed from different radial and azimuthal distances

studying the velocity dispersion between electrons and protons of different energies, using the method of Reinhard and Wibberenz (1974) and Ma Sung et al. (1975) to separate solar and interplanetary propagation processes. They found that the probable acceleration time of the particles is close to 0800 UT on January 5. It is interesting that an impotance 1n flare was reported at 0730 UT on the same day from McMath region 13411 which was at 58° E at this time. On the other hand, the second active region 13404 had produced X-rays and pronounced radio activity during its passage over the visible disk.

As discussed by Green et al. (1975) it is very probable that an interplanetary shock observed at Helios on January 6, 2040 UT, originated from a flare close to the *west* limb on January 5. Thus, both active regions are indeed candidates for the particle acceleration but they are roughly at the same longitudinal distance from the Helios connection longitude. Green et al. (1975) estimated the coronal parameters for this event: a solar drift time of 8 h for the bulk of particles, and of 2 h for the first particles. These parameters are in agreement with the average behaviour for solar events where the originating flare is 80° to 90° away from the observer (Reinhard and Wibberenz, 1974; Ma Sung et al., 1975).

The main interest in this event may come from the study of the shock related increases superimposed on a long decay phase lasting more than three days (see Fig. 5). It should be possible to infer the large-scale structure of the interplanetary magnetic field related with two shocks on January 6 and January 8 from simultaneous measurements on Helios and near earth. This large-scale structure is one of the prerequisites to distinguish between various models of ESP-events. Analysis of the angular distribution of low energy alpha particles and protons shows a preferred streaming of particles *away* from the shock associated structures both before and after the shock passages.

March 3, 1975, Event

The relative location of the two interplanetary field line bundles connecting Helios and the earth to the sun is very similar to the situation in January (see Fig. 5), but at this time Helios is located at 0.41 AU from the sun. The flare occurred probably within the fast propagation region with respect to both Helios and earth. The time profile of this event is very smooth. The onset for the 4–13 MeV protons occurs at 1635 UT on March 3. The maximum intensity is reached 3 h later, followed by a rapid decrease with an e-folding time of ~4.5 h. An attempt to fit this profile with a simple diffusion model and a delta-function injection at the sun leads to a relatively small cosmic ray scattering mean free path of the order of 0.04 AU. In addition, the anisotropy we observed is very large, of the order of 80% and 60% between 5 and 10 h after the onset. These large values are in clear contradiction with a prompt injection at the sun (see e.g. Schulze et al., 1975).

If we take the extreme position that the propagation during this event is totally scatter-free we obtain a decay time constant of 4.5 h. It is interesting to note that this value for protons of this energy range is in good agreement with the conclusion drawn by Reinhard (1975) on the decay times of the solar injection process.

March 19/20, 1975, Event

The days of March 7 through 14, 1975, had been very quiet in the various cosmic ray channels. After March 16, however, when Helios was close to its first perihelion, the sun became rather active in X-rays as seen from Helios (Trainor, private communication). In addition, several small intensity increases occurred in the low energy cosmic ray data. The largest peaks occurred on March 19/20 and are shown in Figure 6 for four selected channels. The peaks are marked as "1", "2", and "3" in the insert to channel A 2–4. We note the following different features in the various channels: (a) Near-relativistic electrons are seen only in peak 1. (b) The onset of peak 1 is rather different for the various channels. The sharp first rise in channel A 2–4 is in coincidence with a sharp interplanetary magnetic field directional discontinuity (Neubauer and Musmann, private communication). After correction of this effect – which leads to a break in the P 4–13 onset phase – one sees the clear velocity dispersion between the electrons and protons. (c) Peak 2 is most clearly seen in the lowest energy Helium counting rates (A 2–4) and seems to coincide with an increase in channel A 4–13. It seems unlikely that the absence of this peak in the proton channel P 4–13 is due to insufficient statistics. (d) The nucleons show a new significant increase around 0800 UT on March 20 (peak 3). Inspection

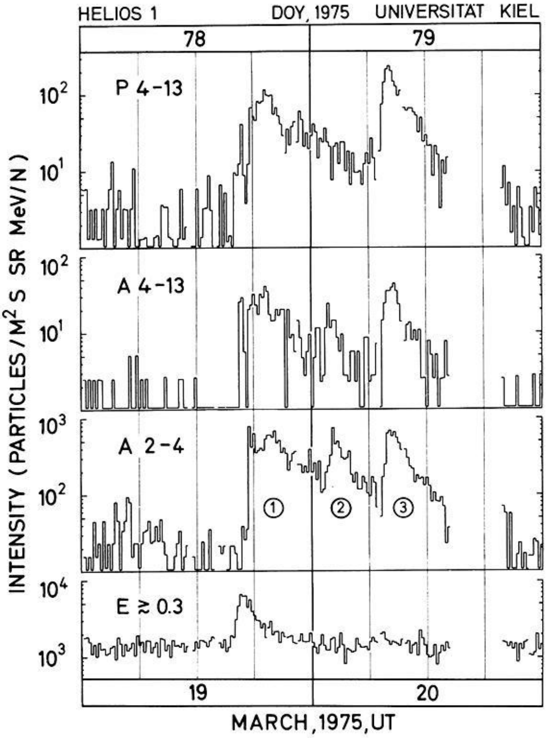

Fig. 6. Intensity variations in selected channels during the ^{3}He-rich events shortly after perihelion

of the anisotropies indicates a new injection of particles from the sun. (e) Rise and decay times are remarkably short for the nucleon channels (decay time of less than 2 h for peak 3). We suggest that this is related to the small distance r from the sun: in a model of diffusive propagation with the scattering mean free path independent of r, time constants vary proportional to r^2. This means that for $r=0.32$ AU the diffusive widening of an intensity-time profile is reduced by a factor of the order of 10 as compared to near-earth observations.

The most interesting feature of this sequence of events is their large He^3 content. Pulse height information from individual nucleons can be used above 4 MeV/nucleon for charge, mass, and energy identification. Within the time interval 1530 UT, March 19, to 1200 UT, March 20, we have identified 225 protons and 80 Helium nuclei in the energy range 5–7 MeV/N.

Figure 7 shows the mass histogram in the range of 3 to 4 nucleon masses for Helium nuclei in the energy/nucleon range from 5 to 7 MeV/nucleon.

Table 2 summarizes the results. For peaks 1 and 2, the ^{3}He/^{4}He-ratio is larger than 2 and does not change from one peak to the other within the statistical limits. For peak 3, the ratio is smaller than one; the difference in the ratio would be consistent with a fresh injection of particles as concluded above under (d) from anisotropies. If we assume power law differential spectra $j(E)=j_0E^{\gamma}$, we obtain $\gamma\simeq-4.5$. Within statistical errors this value does not change between the three peaks and, in addition, does not depend on the particle type.

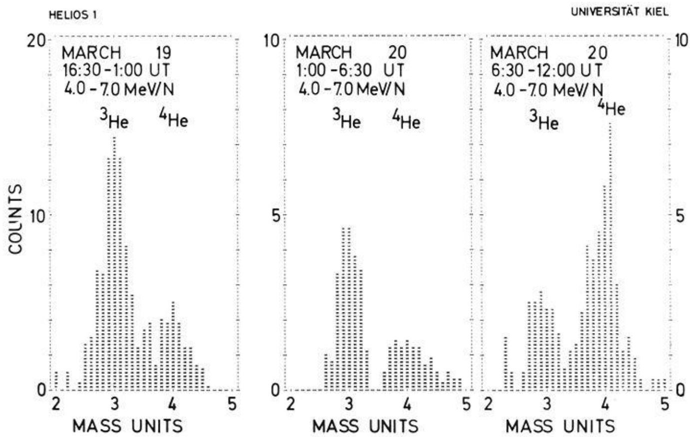

Fig. 7. Mass histograms at different time intervals during the solar particle event of March 19, and 20, 1975 in the Helium range. The histograms clearly demonstrate the separation of ^{3}He and ^{4}He and the high ^{3}He contribution

Table 2. Number of identified Hydrogen and Helium nuclei in the range 5–7 MeV/N and related ratios of ^{4}He/P and ^{3}He/^{4}He

Date Time	March 19 15:30–1.00	March 20 1:00–6:30	March 20 6:30–12:00
P	95	26	104
^{4}He	12	4	12
^{3}He	34	8	10
^{4}He/P	0.13 ± 0.04	0.15 ± 0.08	0.12 ± 0.04
^{3}He/^{4}He	2.83 ± 0.95	2.00 ± 1.22	0.83 ± 0.36

^{3}He-rich events were first reported by Garrard et al. (1973) and Anglin et al. (1974). There is no or only a weak flare correlation, and large He^3 contents are restricted to small events. No measurable amount of Deuterium or Tritium has been found in these events so far. Hovestadt et al. (1975) pointed out that the sun and the interplanetary conditions during the Helium 3 – rich events are very quiet in general and that sometimes the solar wind density is exceptionally high.

Three He^3-rich events are reported by Serlemitsos and Balasubrahmanyan (1975). They find $^3\text{He}/^4\text{He} \simeq 1.5$ for the 1969 May 28 event, and also a relatively small amount of protons, $P/(^3\text{He}+^4\text{He}) \simeq 1$.

We can confirm most of the earlier findings for ^{3}He-rich events for the March 19/20, 1975, case:

– On March 19, Helios is at the peak of a high speed solar wind stream, connected with the north polar coronal hole (Schwenn et al., 1976).

– The events are small; the ratio of alpha particles to protons is larger than on the average in "normal" solar events. No deuterons or tritons are detected.

– There seems to be no (easy) identification with a solar flare. In principle, two active centers on the sun could be the source region. McMath region

13532 was rather active during its passage over the solar disk; it was close to the Helios connection longitude at the time of the events, but about 40° beyond the west limb as seen from the earth. This means that this region could not be observed in H_α after March 16. However, the X-ray data from the Goddard Space Flight Center experiment on board Helios (Trainor, private communication) does not show any X-ray activity from region 13532 prior to peak 1. The time of a subflare in the other active region, McMath 13540, near the magnetic fieldline connection point of the earth (c.f. Fig. 5) corresponds to the observed onset time of peak 1. However, this region showed no significant activity before and after this event. As there is no information related to peaks 2 and 3, the origin of the sequence of events on March 19 and 20, 1975, remains open at this time.

6. Discussion and Summary

We present cosmic-ray results from the first part of the Helios 1 mission for the period December 1974 to June 1975. The level of solar activity is very low, and still decreasing. The inspection of neutron monitor data shows that this period is characterized by a slow increase of the high energy galactic cosmic radiation with a relatively constant rate.

In our discussion of radial gradients and quiet time spectra (section 3 and 4) we have assumed that longitudinal and latitudinal effects can be neglected. The observed variation in the integral > 51 MeV proton channel was interpreted by the superposition of a radial on a temporal variation. The resulting integral radial gradient of (11 ± 2.5)%/AU is larger than obtained previously from the Pioneer 10/11 missions. We discussed several physical reasons for this difference. Possible systematic errors (influence of a variable background and threshold drifts) will be reduced in the future; a detailed study is in progress which makes use of the three detector outputs for energy and particle determination.

During March 1975, the anomalous Helium component is also present close to 0.3 AU. The radial gradient is small. In the energy interval 13 to 47 MeV/nucleon, this component shows an intensity change of about 50% between December 1974 and June 1975; for both of these periods Helios was close to 1 AU. It should be noted that this change of about +50% is accompanied by a 2.7% steady increase of the Deep River neutron monitor counting rate.

In future studies we shall improve the separation of spatial and temporal variations. Neutron monitor data as a reference will be replaced by near-earth satellite observations of particles with energies comparable with those on Helios. In addition, for further investigations of radial gradients and quiet time spectra we will make use of the long lifetime of the Helios mission (as of May 15, 1977, Helios 1 is still in operation, and Helios 2 has delivered additional data since January 1976) and of its orbit: the orbital period of half a year allows to scan the same interval of radial distances from the sun in subsequent phases of the solar cycle; the alternate inward and outward motion will cause radial gradients to be superimposed on existing temporal variations with alternating sign.

Three selected solar particle events were discussed in section 5. With their low particle fluxes they belong to the class of micro events. They represent examples of the very different properties which solar events can exhibit. The January 5, 1975, event shows a long-lasting decay phase. Interplanetary disturbances are partly the reason for considerable modulation during the decay. The March 3, 1975, event has a very regular time structure with smooth and short rise and decay phases. There is some indication that the observed profile is very directly related to the solar injection porcess and only moderately modified by interplanetary propagation. The relative position between Helios 1 and the earth—on closely neighbouring interplanetary magnetic field lines, but about 0.6 AU apart from each other—will be ideal to separate interplanetary and solar transport processes by comparative studies.

The March 19/20 event consists of three different peaks with at least two separate injections. It is of special interest because of its unusual high ^{3}He/^{4}He-ratio of the order of two to three. If observed from earth this event would probably be masked by the background level; furthermore, it seems improbable that the relatively fast time structures would remain undisturbed by interplanetary propagation for an observer located at 1 AU. The presentation of the events observed close to the sun reveals some of the advantages of the Helios orbit for the study of solar events as compared to measurements at 1 AU. Discrimination between repetitive events occurring with small temporal separation is improved. Smaller events can be resolved from background, which is important because small solar events may exhibit some unusual features with respect to chemical and isotopic composition (cf. Gloeckler, 1975). The reduced influence of interplanetary scattering processes allows to draw hitherto unknown conclusions on the particle injection close to the sun. Full advantage of this situation will be taken during the double mission of Helios 1 and Helios 2, in particular in the period March to May 1976, when both spacecraft were relatively close to the sun during a period of minor solar activity.

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