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Search for Peculiarities of Proton Events in Solar Cycle 22 from Ground-Based Observations

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Abstract. Peculiarities of ground increases of solar cosmic rays (SCRs) recorded in solar cycle 22 have been investigated with a neutron supermonitor with high temporal resolution data. The frequency of the events in 1989–1991 was four times the average ($\sim$ 1 year^{-1}) for the whole SCR observation period. The form of the temporal profiles for a number of events in distinguished by a two-hump structure, which indicates the possibility of double emission of SCRs from two different sources. The spectrum of emission for the event of September 29, 1989, is determined as $D_{\odot}(R) = (1-2) \times 10^{32}\ R^{-2.9}$ GV^{-1} for the protons of $R \gtrsim 1$ GV. Judging from the flow of such protons, this event was one or two times weaker than the known one of February 23, 1956. It is shown that the proposed flux of flare neutrinos of September 29, 1989, could not be recorded with the neuntino detectors available.

Introduction

Solar proton events (SPEs) of the current solar cycle 22, are distinguished by some noteworthy peculiarities [*Miroshnichenko,* 1990]. Hence, for physical and practical reasons, researchers often single out the strongest events as a special group. Data on such events are used either for estimating the greatest possibilities of solar acceleration (e.g. the events of February 23, 1956 and September 29, 1989, with high flux of very active particles) or for modeling the worst-case view of radiation danger (events with very strong proton flux of comparatively small energies, e.g. in July 1959, August 1972, and October 1989).

The data in Table 1 on the ground increases of SCRs were developed from the observations of 1989–1992; estimates of some generation and scattering of relativistic protons are also given. The high accuracy of ground-based registration allows investigation of the subtle temporal structure of events and estimation of the properties of SCR sources (i.e., SPE on September 29, 1989).

Observation Data

Of 53 ground SCR increases recorded since 1942, 14 cases are from the current solar cycle. The main features of cycle 22 increases from 1- or 5-min data of the Apatity neutron monitor (rigidity of geomagnetic cut R_c = 0.6 GV) are given in Table 1. One can see that the strongest increases took place on September 29 and October 24, 1989. One of the peculiarities of such events in the current cycle is that series are observed (i.e., in May 1990 a similar active field generated four increases). In the frequency of events another peculiarity has been revealed: the frequency is four times higher than the average of the whole SCR observation period ($\sim$ 1*year*$^{-1}$). Additionally unusual details in the temporal profiles of SPE rates were discovered, and these details may significantly change the traditional interpretation of generation and transport of SCRs (see below). The event of September 29, 1989 is undoubtedly of the most interest, being the third in a number of ground increases after the SPEs of February 23, 1956, and November 19, 1949 [*Smart and Shea,* 1991].

The form of the temporal profile contains important information on the time of SCR emission from the solar corona and the conditions of propagation in interplanetary space. To get such information from the observation data, we have used the parameter $T_{1/2}$ which is the profile width at half of its height. Figure 1 shows the dependence of $T_{1/2}$ on the heliolongitude of the relevant flare (SCR source) from 43 ground increases (31 events have been noted since 1969 at the Apatity station; for earlier events, data from other high-latitude stations have been used). In the distribution, the group

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Table 1. Ground Increases of SCRs in 1989 - 1992 from the Neutrino Monitor Data, Apatity

Date of SPE	Maximum X-ray splash	Flare coordinates	Flare power		Data of Apatity NM-64			
			X-ray 1–8 Å	H_α	Start, UT	Max, UT	Amplitude, %	$T_{1/2}$, h
25.07.89	08.44	$N25W84$	X2.6	2	08.50 ± 5	10.25 ± 5	3.8	2.3
16.08.89	01.18	$S18W84$	X20	2	01.36 ± 1	03.40 ± 5	12.5	3.4
29.09.89	11.33	$S24W105$*	X9.8	–	11.50 ± 1	13.50 ± 5	202	3.9
19.10.89	12.58	$S27E10$	X13B	4B	13.19 ± 1	15.45 ± 5	38	9.8
22.10.89	18.05	$S27W31$	X2.9	2B	18.08 ± 1	18.30 ± 5	17	2.9
24.10.89	18.31	$S30W57$	X5.7	3B	18.30 ± 1	20.35 ± 5	85	6.5
15.11.89	06.50	$N11W26$	X3.2	3B	07.08 ± 1	07.12 ± 1	8	0.2
21.05.90	22.19	$N35W36$	X5.5	2B	22.32 ± 1	22.55 ± 5	14	0.7
24.05.90	20.51	$N33W78$	X9.3	1B	21.45 ± 5	00.35 ± 5	8	5.7
26.05.90	20.58	$-W100$*	X1.4	–	21.24 ± 1	21.45 ± 5	7.5	0.3
28.05.90	04.33	$-W120$*	C1	–	05.35 ± 5	10.15 ± 5	5	7.5
11.06.91	02.09	$N31W17$	X12	3B	02.40 ± 5	03.30 ± 5	8.5	2.6
15.06.91	08.21	$N33W69$	X12	3B	08.46 ± 1	09.25 ± 5	26	1.6
25.06.92	20.14	$N09W67$	X3.9	3B	20.35 ± 5	21.05 ± 5	4.1	1.0

* Indirect estimate; data on maximum X-ray splash time (1–8Å), coordinates, and flare power are from the *Solar-Geophysical Data (1989–1992) Bulletin*. $T_{1/2}$ is the width of the temporal profile increase at half of its height.

of 11 rapid events with $T_{1/2} < 1.0$ h (lower part of Figure 1) is distinct. Three events from the table have also been included in the group; the remaining increases appeared to be slow ($T_{1/2} \gtrsim 1.0$ h). We define "rapid" as those events having an impulse-like profile with sharp growth and decay of intensity. Such a profile shows SCR generation in the open magnetic configuration high in the corona, where particles may escape to interplanetary space. Rapid events differ from slow ones with more rigid energy spectra [*Miroshnichenko and Perez-Peraza,* 1990].

On the whole, the events of cycle 22 have not practically differed from the events of other cycles judged by the $T_{1/2}$ parameter. However, the temporal profile patterns from a number of ground increases have some peculiarities, which can indicate the existence of two SCR components, i.e. rapid and slow (delayed) [*Mirochnichenko and Pevez-Peraza,* 1990]. Figure 2 shows an example of simultaneous recording of rapid and slow components from the data of stations Oulu (neutron monitor) and Apatity (neutron and muon telescope) for the event of September 29, 1989. Intensity profiles from the neutron monitors evidently depict the superposition of two components, rapid and slow, while the muon telescope, sensitive mainly to the original particles with rigidity $R \gtrsim 5$ GV, recorded the rapid component only.

Certain indications on the two-component increase of September 29, 1989, have also been obtained from the data of the Deep River station, Calgary, and a number of others [*Ahluwalia et al.,* 1991; *Smart et al.,* 1991]. At the same time, an apparent trend to the particle source was changing with time; at the beginning of the event (one maximum at 1217 UT), the source was located to the north of the ecliptic plane, and in approximately 1 h (Second maximum at 1315 UT), the highest flux was recorded from the antisolar orientation to the south of the ecliptic [*Smart et al.,* 1991]. The event was notable for a very strong and complicated energetic spectrum [*Smart et al.,* 1991; *Krymsky et al.,* 1990]. *Torsti et al.* [1991] believe that the peculiarities of the temporal profile indicate a double emission of SCRs.

A distinct two-hump increase structure was observed by the neutron monitors of Apatity and Oulu on May 21–22, 1990 ($T_{1/2} = 0.7$ h). A similar effect was noticed on October 22, 1989 at the antarctic stations at the South Pole and McMurdo *Beiber et al.* [1990]. The temporal profile of increase in the Northern Hemisphere (Thule station in Greenland) had no such peculiarities (it was smooth enough), and according to the observed data, this event has not been included to the class of rapid ones ($T_{1/2} = 2.9$ h). Two-component superposition of an increase less distinct but not notable enough was recorded at the Apatity station on April 25, 1990 ($T_{1/2} = 0.3$ h). Below, the main attention is given to the parameter estimates of generation and propagation of relativistic protons as recorded by ground-based stations on September 29, 1989.

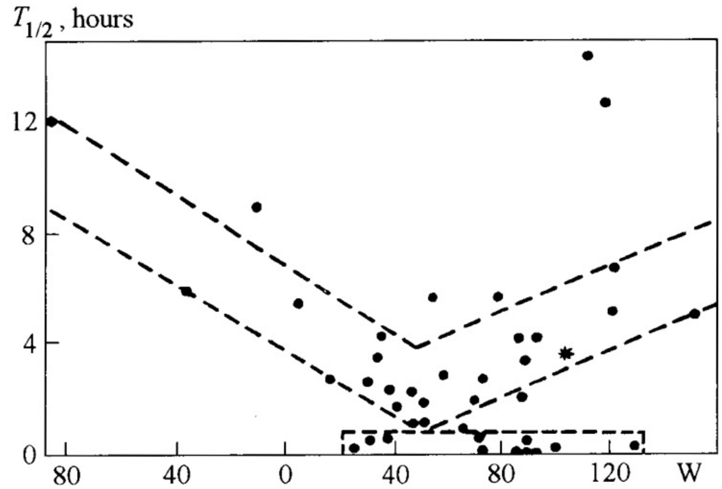

Figure 1. Heliolongitudinal distribution of temporal profiles of relativistic SPEs from the $T_{1/2}$ parameter. An asterisk marks the proton event of September 29, 1989.

Properties of the SCR Source of September 29, 1989

The relativistic proton source in the September 29, 1989, event was undoubtedly a strong enough flare, which was seen on X-ray film (X9.8 at 1047 UT). Judging from the radio observations at 5.2 cm [*Maksimov and Nefedyev,* 1991] before the flare, there was an outburst of a slaw filament located to the south of AO 5698, with subsequent coronal substance emission, which led to the shielding of the S-component source over the AO. The degree of radiation polarization, high brightness temperature, and great height of the source above the limb served in this case as additional indications of the existence of a preflare situation. The configuration of magnetic fields over AO 5968 has remained unknown, although an effective loop structure that existed for more than 10 h was distinctly observed [*Shea and Smart,* 1989]. Totality of these data permits one to apply to the event of September 29, 1989, the hypothesis of [*Perez-Peraza et al.,* 1992] on the existence of two sources of acceleration with rapid and slow SCR component generation (I and II maximums, respectively). The source of the rapid component may be located high in the corona far from the flare location, which is the source of the SCR slow component.

Parameters of SCR Propagation on September 29, 1989

If the event had two sources of particles scattered in time and space, then the analysis of SCR transport becomes a nontrivial task, as neither source coordinates nor moments of accelerated-particle generation are known accurately. On the basis of the data [*Smart et al.,* 1991], one can only affirm that the difference between the emission moments did not exceed 1 h. One can suppose that near the Earth's orbit the superposition of two SCR fluxes occurred. That is why without individual analysis the temporal profiles for the diffusion parameters do not present any special interest. Nevertheless, a number of researchers [*Miroshnichenko,* 1992] made attempts to apply various modifications of diffusion description to the observation data of this event. For instance, *Philippov et al.* [1991] revealed that the form of the intensity decay may be approximately described with two exponential functions exp $(-t/\tau_d)$, where the typical decay time depends on proton energy and grows with time. One of the causes of such an effect may be the existence of reflection diffusion shell at a distance of $r \gtrsim 5$ a.e. from the Sun. However, in the absence of any data on structure and solar wind in the period under review, this interpretation [*Philippov et al.,* 1991] cannot be admitted as the only one. Not discussing the correctness of the diffuse approach to this event on the whole, the authors give the results of their analysis, which was being done independently in order to estimate the degree of applicability of traditional diffuse description, at least at the late enough stage of the event ($t \gtrsim t_{\max}$).

The analysis was done by using data from three neutron monitors: Moscow (R_c = 2.35 GV), Apatity (R_c = 0.60 GV), and Mirny (R_c = 0.02 GV). For the choice of an adequate model of SCR propagation the decay temporal profile was approximated by exponential and/or power functions (with typical interval τ_d and/or indication of degree, respectively) for various intervals, and then average difference values $\overline{\tau}_d$ and $\overline{\alpha}$ were chosen. These values for the Apatity (Ap) and Mirny (Mr)

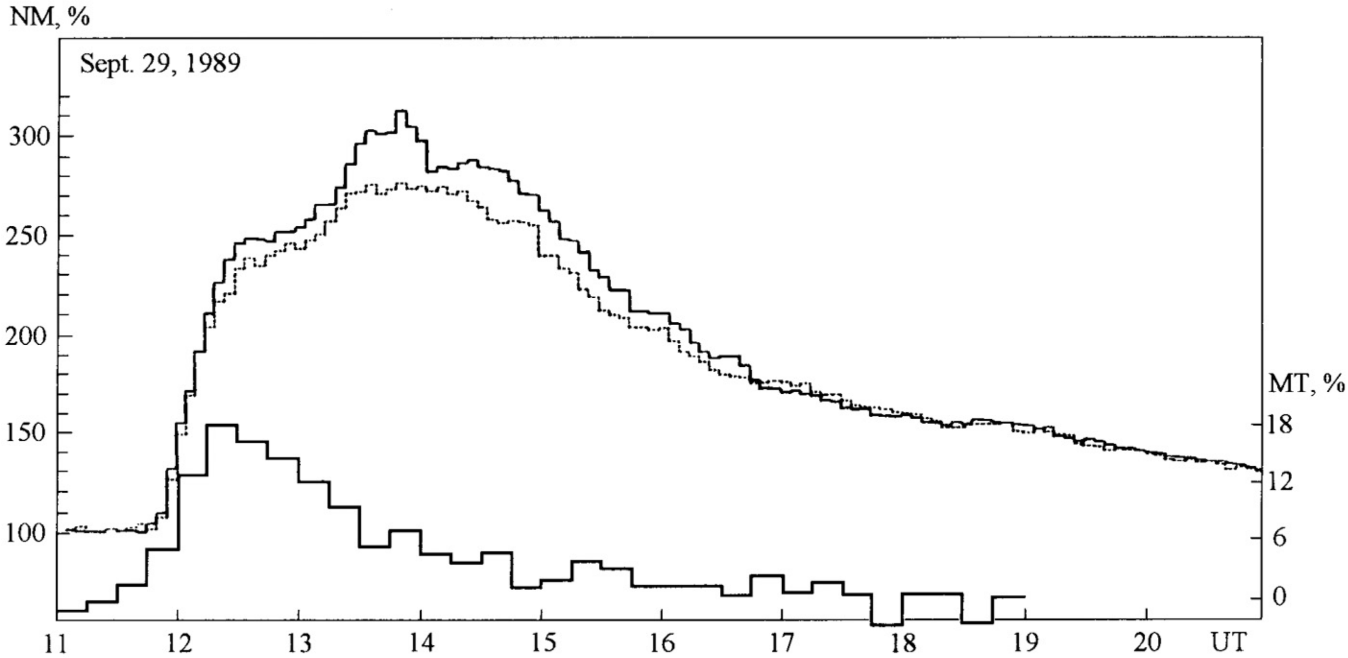

Figure 2. Temporal profiles of the event of September 29, 1989, from the 5-min data of the Apatity (solid line) and Oulu (dotted line) neutron monitors and from 15-min data of the muon telescope at Apatity (below).

stations were close: $\overline{\tau}_d$ (Ap) = (4.4 ± 0.5 h, $\overline{\alpha}$ (Ap) = 2.25 ± 0.3; $\overline{\tau}_d$ (Mr) = 4.4 ± 0.5 h, $\overline{\alpha}$ (Mr) = 2.15 ±0.7. The authors estimate that the decay at these stations is better described by a power function than by an exponential one, which somehow limits the choice of propagation model. From the Moscow station data ($\overline{\tau}_d = 2.75 \pm 0.3$ h, $\overline{\alpha} = 1.95 \pm 0.35$) it is more difficult to make such a choice: obviously, SCR propagation in the areas $R > 2.35$ GV and $R \sim 1$ GV took place in different ways.

For the model description of these data there was a solution of the diffusion formula [*Krymsky,* 1969] with $\kappa_{\parallel}(r) = a\kappa_{\perp}(r)$, where $\kappa_{\parallel}$ and $\kappa_{\perp}$ are the coefficients of diffusion along and across the radius respectively, $\kappa_{\parallel} \sim r^{\beta}$, $\beta \geq 0$ were chosen first, and the source is considered to be a point and instantaneous. Analysis has shown that temporal profiles at these stations with $t \gtrsim t_{\max}$ are sufficiently described by the solution [*Krymsky,* 1969] then if $t_{\max}$ (Ap) = 7500 s, $t_{\max}$ (Mr) = 7200 s, and $t_{\max}$ (Ms) = 3900 s, then $\beta \approx 0.7$ (for Apatity and Mirny).

Using the solution [*Krymsky,* 1969] as a Green function integral smothins, one can attempt to resolve the inverse, that is, to reconstruct the temporal emission profile and SCR energetic spectrum close to the Sun from the data for the growth stage and first stage of intensity decay of SCRs near the Earth. At the same time, according to estimates [*Miroshnichenko and Petav,* 1985], it may be accepted that $\kappa_{\parallel} \sim \epsilon_k^{\sigma}$, where $\sigma = 0.5 - 0.8$ (ϵ_k - kinetic energy of protons).

As with the Green function, one can also use a solution of the diffusion equation [*Fibich and Abraham,* 1975] at a boundary condition of a strong magnetic field as shown in [*Fibich and Abraham,* 1975], at the initial stage of SPE, the anisotropic diffusion should be observed, and at large intervals, diffusion becomes isotropic. On the basis of the solution [*Fibich and Alraham,* 1975] modified by the authors and taking into account the dependence $\kappa_{\parallel} \sim r^{\beta}$, they made an attempt to reconstruct a differential spectrum of relativistic proton emission with $R \gtrsim 1$ GV in the form $\sim R^{-\gamma_{\odot}}$. The solution of such an inverse sum by the method of *Miroshnichenko and Sorokin* [1985] gave the value $\gamma_{\odot} = 4.0 \pm 1.5$ which, within the limits of the error of the method, is comparable with the result [*Filippov et al.,* 1991] $\gamma_{\odot} = 3.4 \pm 0.3$, obtained with the help of the simplest diffusion model for the interval $R = 2-150$ GV. Estimates of the typical proton emission interval with $R \gtrsim 1$ GV gave the value $\tau_{\odot} = 20 \pm 10$ min.

Low accuracy of the $\gamma_{\odot}$ and $\tau_{\odot}$ estimates is determined in the authors' view not by the errors of methods [*Filippov et al.,* 1991; *Miroshnichenko and Sorokin,* 1985] but by the limited nature of the diffusion approach to the description of the event of September 29, 1989. At the same time, the diffusion interpretation of temporal motion is also possible. Suppose, for example, that the formation of the temporal profile at the Apatity station ($t_{max} = 2$h, effective protons' energy $\epsilon_p \gtrsim 2$ GV) occurred mainly at $t \lesssim t_{max}$ with transverse diffusion and at $t > t_{max}$ when the longitudinal diffusion prevailed. Then we obtain $\kappa_\perp = r^2/6\ t_{max} = 5.2 \times 10^{21}$ cm^2 s^{-1}. On the other hand, if we take from *Miroshnichenko and Petrov* [1985] a typical value of $\Lambda_\parallel$ (2 GV) $= 3.3\times10^{12}$ cm, we obtain $\kappa_\parallel = \Lambda_\parallel v/3 = 3.15\times10^{22}$ cm^2 s^{-1}. Thus in the observed sphere of energies (2 – 10 GV) the comparable delayed growth stage of the SCR intensity of September 29, 1989, can evidently be explained by transverse diffusion, where $a = \kappa_\perp/\kappa_\parallel \lesssim 0.165$. The obtained value of a is not at variance with traditional concepts about particle transfer into the interplanetary magnetic field [*Krymsky,* 1969; *Miroshnichenko and Petroy,* 1985].

Such estimates are of use if the source of SCR emission of September 29, 1989, was unique. If there were two sources, the diffusion concept is evidently suitable only for the second peak in the temporal profile, and the first one, fastest of all, corresponds to the propagation of a relativistic proton beam along the force lines practically without scattering. The last notion is affirmed by the behavior of anisotropic protons with a rigidity $R \gtrsim 3$ GV [*Smart et al.,* 1991].

Emission Spectra of SCRs

As shown above, uncertainty of the source location of the SCRs (September 29, 1989) does not permit a reconstruction of the emission particle spectra by means of diffusion models that is reliable enough. That is why *Perez-Peraza et al.* [1992] attempted to estimate the emission spectrum using the independent method from the data for first-growth stage (1217 UT). For that moment the observed differential spectrum of the oriented SCR flux had the form [*Smart et al.,* 1991] $D^I_{\underset{\odot}{+}}(R) = 9.32\ R^{-2.9}$ cm^{-2} s^{-1} sr^{-1} GV^{-1}. Neglecting the scattering of the relativistic protons on their way from the Sun to Earth [*Perez-Peraza et al.,* 1992], we obtain, according to the approximate procedure, the maximum estimation of the emission spectrum $D^I_\odot(R) = (1-2)\times10^{32}\ R^{-2.9}$ GV^{-1}. Hence, the maximum number of emitted protons with a rigidity $R \geq 1$ GV did not exceed $N^I_\odot(\gtrsim 1$ GV$) \sim 10^{32}$. In the second maximum (1327 UT), the spectrum at the Earth had the form $D^{II}_{\underset{\odot}{+}}(R) = 15.21\ R^{-2}$ cm^{-2} s^{-1} sr^{-1} GV^{-1} [*Perez-Peraza et al.,* 1992], and the emission spectrum was $D^{II}_\odot(R) = (1.6 - 3.2)\times 10^{32}\ R^{-3}$ GV^{-1} if the same procedure was used for the spectrum estimation. This gives practically the same value: $N^{II}_\odot(\geq 1$ GV$) \lesssim 10^{32}$. In comparison with these values, the estimate [*Filippov et al.,* 1991] $N_\odot$ (≥ 2 GV) $= 1.5\times10^{35}$ seems to be too high (it exceeds even the value obtained by the strongest SPE of February 23, 1956; see below).

It is interesting to compare data on spectra and absolute intensities of relativistic protons for SPE of February 23, 1956, and September 29, 1989. According to *Miroshnichenko* [1970] the spectrum of the direct SCR flux of February 23, 1956, at the Earth had the form $D^{\Pi}_{\underset{\odot}{+}}(R) = 6.36\times10^2\ R^{-3.5}$ cm^{-2} s^{-1} sr^{-1} GV^{-1}, which differs a little from the estimation of [*Smart and Shea,* 1990] $D^{\Pi}_{\underset{\odot}{+}}(R) = 5\times10^2\ R^{-3.5}$ in the same units. From the comparison with data of *Smart et al.* [1991] one can see that the event of September 29, 1989, was one to two times weaker by the flux of protons with rigidity $R \gtrsim 1$ GV. A similar conclusion follows from the comparison of emission spectrum obtained above $D^I_\odot$ and $D^{II}_\odot$ for the event of September 29, 1989, with the respective spectrum for the event of February 23, 1956 [*Perez-Peraza et al.,* 1992]: $D_\odot(R) = (1.1 - 2.2)\times10^{33}\ R^{-3.5\pm0.2}$ GV^{-1} from which is obtained $N_\odot(\geq 1$ GV$) \lesssim 10^{33}$ protons.

Generation of Flare Neutrinos and Probability of Recording Them

In light of the given estimates, let us discuss the probability of recording flare neutrinos by means of existing and projected detectors. Decisive parameters for such recording are, on the one hand, intensity and orientation of the relativistic proton beam ($R \gtrsim 1$ GV) in the Sun's atmosphere and, on the other hand, the sensitivity of the specific detector of high energy neutrinos. From the generation conditions, flare neutrinos of the electron type have maximum intensity in the energy region $\epsilon_\nu \sim 10$ MeV with isotropic distribution and in the interval $\epsilon_\nu \simeq 10 - 100$ MeV at various angles θ relative to the orientation of the original proton beam [*Kocharov et al.,* 1990]. So the flux of isotropic neutrinos is 5 – 10 times smaller than that for anisotropic generation. Generation speeds and spectra of muon neutrinos and antineutrinos differ insignificantly from the same estimates ν_μ, and the flux of electron antineutrinos $\overline{\nu}_\mu$ is much lower than that ν_e. The probability of recording by this detector will evidently depend on the kind and energy of neutrino and on the value of θ as well.

As is shown in a review [*Kocharov,* 1991], the sensitivity of existing radiochemical detectors (^{37}Cl and ^{71}Ga) and direct count detectors (Kamiokande II, IMB, Baksan, LVD) are several orders of magnitude lower than is necessary for the recording of flare neutrinos in the most "optimistic" conditions of their generation (narrow beam of relativistic protons with a rather rigid spectrum from the flare on the invisible side of the Sun). That is why one should speak about flare neurino recording only as a possibility whose realization is connected to the creation of neutrino detectors of a new generation.

One such detector of direct registration was examined theoretically by *Erofeeva et al.* [1983]. A water detector with a mass of about 10^6 can record muon neutrinos by Cherenkov radiation of muons generated in reactions with nuclear targets (H_2O). Estimates [*Erofeeva et al.*, 1983] show that the necessary number of relativistic protons for the certain recording of neutrinos (for a sufficient flux ν_μ generation at a flare) is $N_p(\geq 1\ \mathrm{GV}) \geq 10^{32}$ at isotropic generation (narrow proton beam from a flare on the visible side of the Sun). According to estimates [*Kocharov et al.*, 1990], a necessary number of protons can be decreased 5–10 times.

From the data on emission spectra for the SPE of February 23, 1956, without division of the SCRs into rapid and slow components, *Miroshnichenko* [1990] obtained $N_p(> 1\ \mathrm{GV}) = 6.1\times10^{32}$ with maximum rigidities of accelerated protons $R_{\max} \gtrsim 20$ GV (the accuracy of the estimate N_p is within a factor of $\gtrsim 2$). It is not difficult to note that this estimate [*Mirishnicnenko*, 1990] in terms of uncertainties is compatible with the value of $N_\odot$ (≥ 1 GV) $\lesssim 10^{33}$ given above, obtained by *Perez-Peraza et al.* [1992] from the data for the fast component only.

As shown above for the event of September 29, 1989, the value N_p (≥ 1 GV) should be reduced by 1–2 orders of magnitude. This means that for this detector, a flare of September 29, 1989, could not be observed and a flare of the February 23, 1956, type would be observed, especially in the optimum orientation of the relativistic protons beam. In our opinion, the "efficient" orientation can be ensured not only by strongly antipodal flare location (on the Sun's invisible side) but also by the geometry of coronal fields near the source of the SCR rapid component [*Perez-Peraza et al.*, 1992]. That is why, besides the detector's heightened sensitivity for flare neutrino recording, it is also necessary to have rare auspicious geometry of magnetic fields in the source area. In spite of this pessimistic conclusion, we do not doubt the importance of the search for flare neutrinos, which can answer a number of critical questions in flare physics: the value of $R_{\max}$ acceleration mechanism, source height in the Sun's atmosphere, and acceleration rate up to relativistic energies.

Conclusion

The main results of the work presented here are as follows.

1. The data on SCR ground increases are generalized for the first six years of solar cycle 22. Some peculiarities of proton events in the area of rigidities $R \gtrsim 1$ GV (heightened frequency and serial character of events, two-hump form of temporal profiles) have been revealed.

2. For the SPE of September 29, 1989, the limited nature of the diffusion approach to the description of the temporal profile of growth has been shown arguments for the hypothesis about double emission of SCRs from two different coronal sources have been given and spectra of proton emission with $R \gtrsim 1$ GV for the first and second growth peaks have been reconstructed in the form $D^{I}_{\odot}(R) = (1-2)\times10^{32}\ R^{-2.9}\ \mathrm{GV}^{-1}$ and $D^{II}_{\odot} = (1.6-3.2)\times10^{32}\ R^{-3}\ \mathrm{GV}^{-1}$ respectively.

3. It has been shown that the expected neutrino flux from the flare of September 29, 1989 could not be recorded by existing neutrino detectors.

Analysis of relativistic SPE of cycle 22 has revealed a number of contradictions and uncertainties in the interpretation of spectral, temporal and angle characteristics of SCRs (*Miroshnichenko*, 1992]. The interpretation complication is conditioned by the revealing of the subtle structure of temporal profiles (due to the increased accuracy of ground-based recording of SCRs). It is not possible to ascribe details of the profile by a unique model of generation and transport of the particles in terms of accepted concept (see Results [*Miroshnichenko and Sorokin*, 1985]). Besides that, it remains unknown why the cases of ground increases are observed in groups while the events take place over several days and their average frequency is $\sim 1\ \mathrm{year}^{-1}$. The probable cause of the serial character of SPEs seems to be a specific configuration of the magnetic field in the corona that exists for a long time and slowly evolves as the active field is being developed.

In conclusion, we briefly ascribe the probable plan of the event of September 29, 1989, on the basis of a model of two-component particle generation (emission) [*Perez-Peraza et al.*, 1992]. First an impulse-like increase, observed even by underground muon telescopes with effective energies higher than 100 GV [*Philippov et al.*, 1991] could be triggered by acceleration high in the corona during the rapid reconnection of magnetic fields (by our estimates [*Perez-Peraza et al.*, 1992], the maximum energy of SCRs accelerated in such a way can exceed 250 GV). During this period the base of the force line connecting the Sun and the Earth was projected on the visible disk to the field that was connected with open structure along the equator-heliospheric current layer [*Fischer and Vashenuyk*, 1992]. Such configuration could motivate rapid input of the particles from the coronal source. This fact evidently conditioned a very strong anisotropy, observed during the first 5 h of the event.

The second injection had a smoother character than the first and was conditioned by particles delivered from the magnetic bottle from the out-of-limb source ($S24$, $W105$). By means of drift and diffusion in the solar corona [*Alvares-Madrigal et al.*, 1986], these particles were transferred to the background of the heliospheric current layer where the Earth was located during the flare of September 29, 1989 [*Fischer and Vashenuyk*, 1992]. Next SCR transport in the layer evidently occurred with the same speed as after the first injection, and near the Earth, the superposition of particle flux was observed from both sources. If this version is accepted, the temporal difference between the first and second injections is still uncertain, as in this case the moment of the magnetic bottle origination is unknown. The analysis of data on two-component events from the flares on the visible side of the Sun (October 22, 1989, May 24, 1990, and others) seems to be more reliable.

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