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# INTERRELATION BETWEEN THE SOLAR SOURCES OF INTERPLANETARY PLASMA STREAMS AND TYPES OF LONG AURORAL DISTURBANCES ON EARTH

M.G.Gelberg, S.Z.Keshengolts, S.V.Sharaeva
*(The Institute of Cosmophysical Research and Aeronomy of Yakutsk Science Centre of RAS, Yakutsk, Russia)*

**Abstract**. A possibility to determine the interrelation between solar sources of corpuscular streams and types of long auroral disturbances (LAD) on Earth is shown. It is found out, that streams from coronal holes and from the Helmet Coronal Streamers result in LAD of the first type, the filament streams produce LAD of the second type, streams from flares - LAD of the third type. The solar sources of auroral disturbances of the fourth type, coinciding (or at least including) with periods of steady magnetosphere convection [1], are not determined so far.

## Introduction

The study of geoefficiency of disturbed streams of the solar wind from various solar sources is a traditional task of the physics of solar-earthly relations [2].

In paper [3] the distribution of the $A_p$ index was devided into four overlapping intervals and it was shown, that geomagnetic disturbances with daily average values of $A_p$ ranging from 28 to 72 nT are caused by flares in the Sun of the point 1 and up, disturbances from $12<A_p<36$ nT are induced by coronal holes, disturbances from $6<A_p< 20$ nT by filaments and filament cavities. In [4], it is noted, that geoeffective streams of interplanetary plasma found at the Earth orbit are most of the time of a complex nature, having been formed in the interaction of isolated streams from several solar sources. At the time of solar activity maximum complex streams make 85% of their total number. In the same paper, the classification of complex streams, observed during 1978 and 1979 is suggested.

The goal of the paper is to show, that in the situation of complex interacting streams it is still possible to determine the interrelation between classes of solar sources and types of long auroral disturbances (LAD), defined in the paper [5], taking into consideration the principle (substantiated in [6]) of domination of geoefficiency of one of the isolated streams in complex events.

## Initial data and their analysis

The list of events, published in [4], observed in 1978-79, involving isolated and interacting streams of interplanetary plasma, was chosen for the analysis. For each event, using the data on auroral indices, there were defined periods of long auroral disturbances and the classification of LAD has been carried out. In a number of events, when auroral disturbances belonged to the intermediary type, they were classified as a type, to which they fit closest and the type, similarity with which had been noted, was given in brackets. The classification of LADs by types was carried out both visually and by means of discriminant analysis. The table contains stream classes, introduced in [4], dates of events, onset and end time of LADs. If the onset and end of LAD fell within different days, the latter were given in brackets. In column 5, results of LAD classification by types are given. Altogether, there were examined 56 events.

One can see from the table, that from 10 events of isolated streams of disappearing filaments (SDF-streams) in 8 events, the LAD of second type was observed. The probability of the second type LAD appearance in years 1978-79 was equal to 0.27 and mathematical estimation of this type LAD in the sampling of 10 events was equal to 2,7. The criterion $\chi^2 = (8-2.7)^2 /2.7 = 10.4$ shows, that the probability of random coincidence of SDF-streams getting to the Earth and of the second type LAD observations makes less than 1%. Thus, we may consider this as determined that SDF streams induce the second type LADs.

There were not registered any isolated streams from coronal holes (CH), from Helmet Coronal Streamers (HCS) or subflares (sf) [2]. However, according to [6], in composite streams, the geoefficiency of one isolated stream is, as a rule, dominating. Within this period the space-time variations of IMF $B_z$ velocity and density of the solar wind plasma are approximately same as those of isolated dominating streams. Geoefficiency of isolated streams from different solar sources is varied. This made it possible to identify relations of Solar source $\rightarrow$ LAD type after events with different classes of interacting streams. For this purpose, a procedure, similar to the soft rating «poll» was used. Various combinations of relationship were considered; the class of source $\rightarrow$ the LAD type number: SDF$\rightarrow$2, CH$\rightarrow j_1$, HCS$\rightarrow j_2$, sf$\rightarrow j_3$, where $j_1$, $j_2$, $j_3$ - are numbers of suggested LAD types.

Classes of streams near the Earth orbit and types of LAD Table

| № | Classes of interplanetary plasma streams | Dates | Times of onset and end of LAD, UT | Type of LAD | Variant | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | SDF→2 | CH→1 | HCS→1 | sf→3 |
| 1 | SDF | 14/04/78 | 0-24 | 1(2) | | | | |
| 2 | | 5-6/04/78 | 19(5)-17(6) | 2 | | | | |
| 3 | | 8-9/07/78 | 15(8)-4(9) | 2 | | | | |
| 4 | | 21/07/78 | 0-13 | 2 | | | | |
| 5 | | 7-8/09/78 | 23(7)-9(8) | 1(2) | | | | |
| 6 | | 12-14/09/78 | 22(12)-4(14) | 2 | | | | |
| 7 | | 17/09/78 | 4-10 | 2 | | | | |
| 8 | | 5-6/09/78 | 21(5)-17(6) | 2 | | | | |
| 9 | | 18-19/11/78 | 14(18)-4(19) | 2 | | | | |
| 10 | | 22-23/06/78 | 5(22)-14(23) | 2 | | | | |
| 11 | SDF+CH | 9-10/01/78 | 16(9)-12(10) | 1(2) | 0,5 | 1 | | |
| 12 | | 8-9/05/78 | 23(8)-24(9) | 1(2) | 0,5 | 1 | | |
| 13 | | 16-17/08/78 | 11(16)-4(17) | 4(2) | 0,5 | | | |
| 14 | | 18-19/08/78 | 17(18)-2(19) | 2 | 1 | | | |
| 15 | | 19/11/78 | 8-20 | 2(1) | 1 | 0,5 | | |
| 16 | | 20-21/11/78 | 1(20)-2(21) | 3(1) | | 0,5 | | |
| 17 | | 22/11/78 | 3-22 | 1 | | 1 | | |
| 18 | | 25/11/78 | 0-24 | 1 | | 1 | | |
| 19 | | 18-20/12/78 | 4(18)-24(20) | 1 | | 1 | | |
| 20 | SDF+HCS | 9-10/12/78 | 6(9)-2(10) | 1 | | | 1 | |
| 21 | | 22-23/01/78 | 11(22)-1(23) | 2 | 1 | | | |
| 22 | | 3-4/08/78 | 5(3)-4(4) | 2 | 1 | | | |
| 23 | | 25/08/78 | 7-20 | 2 | 1 | | | |
| 24 | SDF+sf | 17/04/78 | 3-13 | 3(4) | | | | 1 |
| 25 | | 16-17/06/78 | 10(16)-22(17) | 2(4) | 1 | | | |
| 26 | | 18-19/07/78 | 11(18)-18(19) | 2(3) | 1 | | | 0,5 |
| 27 | | 6/09/78 | 4-17 | 3(2) | 0,5 | | | 1 |
| 28 | CH+sf | 29/09/78 | 3-19 | 1 | | 1 | | |
| 39 | | 29-30/12/78 | 16(29)-2(30) | 1(3) | | 1 | | 0,5 |
| 30 | | 30/12/78 | 2-16 | 3 | | | | 1 |
| 31 | | 6-7/07/79 | 5(6)-12(7) | 3 | | | | 1 |
| 32 | | 7/07/79 | 12-22 | 1 | | 1 | | |
| 33 | | 29/08/79 | 5-24 | 1 | | 1 | | |
| 34 | SDF+CH+HCS | 26-27/10/78 | 12(26)-14(27) | 1(3) | | 0,5 | 0,5 | |
| 35 | | 3-4/12/78 | 16(3)-2(4) | 2 | 1 | | | |
| 36 | | 4-5/12/78 | 10(4)-5(5) | 2(3) | 1 | | | |
| 37 | | 25/12/78 | 7-17 | 1 | | 0,5 | 0,5 | |
| 38 | SDF+CH+sf | 17/02/79 | 10-22 | 2 | 1 | | | |
| 39 | | 18-19/02/79 | 3(18)-11(19) | 3(2) | 0,5 | | | 1 |
| 40 | | 19/02/79 | 12-22 | 2 | 1 | | | |
| 41 | | 20-21/02/79 | 15(20)-1(21) | 2 | 1 | | | |
| 42 | SDF+HCS+sf | 13-14/02/78 | 15(13)-19(14) | 2 | 1 | | | |
| 43 | | 19-20/06/78 | 6(19)-3(20) | 2 | 1 | | | |
| 44 | | 14/12/78 | 1-24 | 3(2) | 0,5 | | | 1 |
| 45 | | 25-26/01/79 | 8(25)-2(26) | 1(3) | | | 1 | 0,5 |
| 46 | | 11-12/02/79 | 19(11)-14(12) | 1 | | | 1 | |
| 47 | CH+HCS+sf | 4-5/01/78 | 23(4)-14(5) | 1 | | 0,5 | 0,5 | |
| 48 | | 30/04/78 | 10-24 | 1 | | 0,5 | 0,5 | |
| 49 | | 1/05/78 | 2-24 | 1 | | 0,5 | 0,5 | |
| 50 | | 2/05/78 | 0-24 | 1 | | 0,5 | 0,5 | |
| 51 | | 4/06/78 | 0-15 | 3 | | | | 1 |
| 52 | | 4-5/06/78 | 20(4)-14(5) | 1 | | 0,5 | 0,5 | |
| 53 | SDF+CH+HCS+sf | 2/06/78 | 6-21 | 1(2) | 0,5 | 0,5 | 0,5 | |
| 54 | | 2-3/01/79 | 11(2)-5(3) | 1(3) | | 0,5 | 0,5 | 0,5 |
| 55 | | 25-26/01/79 | 2(25)-2(26) | 1(3) | | 0,5 | 0,5 | 0,5 |
| 56 | | 3/01/79 | 8-24 | 3(1) | | 0,25 | 0,25 | 1 |
| | | | | $N_1$ | 34 | 33 | 23 | 29 |
| | | | | $\Sigma_1$ | 17,5 | 15,25 | 8,25 | 10,5 |

The estimation of relationship variant probability was carried out as follows. In each of 46 events of complex streams, the point 1 was given each pair - source → type number, if the LAD type, indicated in the 5-th column of the Table corresponded to the suggested one for the given source or 0,5 point, if it was noted in column 5, that for this source, LAD had signs of the suggested type. If in the analyzed variant it was assumed, that 2 solar sources caused the same type of LAD and isolated streams from both sources were found in the given complex stream, then, 0,5 point was given instead of 1 and 0,25 instead of 0,5. Further on, for each pair - source→type number, $\Sigma_1$ points totals were calculated for the events, in which there was a stream from the given solar source, $N_1$ - the number of such events and $\Sigma_2$ points total and $N_2$ number for events, in which there were no streams from the given solar source. In the last four columns, «poll» results were given, $\Sigma_1$ and $N_1$ for the most probable variant of combinations - source → LAD type, for which all differences $\Delta=\Sigma_1-\Sigma_2$ were maximal. The reliability of relationship was estimated after the $\chi^2$ - criterion by contingency tables:

| | |
|---|---|
| $N_1$ | $N_2$ |
| $\Sigma_1$ | $\Sigma_2$ |

Below are given 3 contingency tables for SDF, sf, CH, HCS - sources. In this analysis coronal holes and helmet coronal streamers were considered as one solar source, causing auroral disturbances of type 1. For an SDF -source only events with complex streams were considered (46) and for the rest - all 56 events.

| SDF | | sf | | CH and HCS | |
|---|---|---|---|---|---|
| 34 | 12 | 29 | 27 | 41 | 15 |
| 17,5 | 0 | 10,5 | 2 | 23,5 | 2 |

The $\chi^2$ statistic data, calculated by these contingency tables were equal to 5,76 for SDF streams, 5,58 for sf and 4,62 for CH HCS streams. Critical values of $\chi^2_{0,95} = 3,84$. The fiducial probability of the relationship between solar sources and types of LAD exceeded 0,95.

**Conclusion**

It has been found that identification of relations between solar streams sources classes → LAD types, can be carried out for events with interacting streams from several solar sources. It was shown, that SDF-streams cause most often the 2-d type LAD, sf -streams produce the 3-d type LAD, and streams from coronal holes and HCS produce the 1-st type LAD.

The traced relations do not mean, other solar sources, not considered above, can not produce any of the above listed LAD types. Unfortunately, so far, we din not manage to identify the solar source of plasma streams, producing the LAD 4-th type - periods of steady magnetospheric convection.

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