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ALGORITHM AND PROGRAM FOR INFORMATION PROCESSING WITH THE "FILIN" APPARATUS

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16. Abstract

This work describes the algorithm and encloses the program (language "Fortran-4") for identifying segments of information obtained from the telescopespectrometer "Filin", that are "suspicious" for the presence of an x-ray source. In accordance with [1] the proposed algorithm is an algorithm of the lowest level. The information that is freed of uninformative segments is evaluated by the organizers of the experiment and subject to further processing with the involvement of algorithms of a higher level.

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ALGORITHM AND PROGRAM FOR INFORMATION PROCESSING WITH THE "FILIN" APPARATUS

by L. S. Gurin, V. S. Mokrov, Ye. I. Moskalenko and K. A. Tsoy

This work describes the algorithm and encloses the program (language "Fortran-4") for identifying segments of information obtained from the "Filin" telescope - spectrometer that are "suspicious" for the presence of an x-ray source. In accordance with [1] the proposed algorithm is an algorithm of a lower level. The information that is freed of uninformative segments is evaluated by the experiment organizers and is subjected to further processing with the involvement of algorithms of a higher level. /2*

1. Content of Experiment

On the station "Salyut-4" that was launched on 26 December 1974 the "Filin" telescope-spectrometer was installed that was designed to record radiation from space sources in the range 0.2-10 kev. In order to obtain spectral characteristics of the source the given energy range was divided into 6 subranges: 0.2-0.6 kev (channel F1-5), 0.6-0.9 kev (F1-6), 0.9-2 kev (F1-7), 2-3.1 kev (F1-1), 3.1-5.9 kev (F1-2), and 5.9-10 kev (F1-3). In addition, there were two more summary channels: F1-8 (0.2-2 kev) and F1-4 (2-10 kev), and a channel that recorded the background of charged particles, F1-12. The mechanical slit collimators limit the visual field of the x-ray detectors to 3x10° with respect to the half-width of the beam pattern. The instrument readings recorded on magnetic tape after primary processsing of information are values /3

*Numbers in margin indicate pagination in foreign text.

of the rates of counting in each channel.

The "Filin" apparatus operated about 120 hours in different patterns. For a detailed description of the instrument and operating patterns see [2]; here we will only examine the pattern of orientation in the local zenith at which the position of the optic axis of the telescope during movement of the station was maintained in the direction of the local vertical, while the visual field of the instrument was moved over the celestial sphere perpendicular to the broad side with a velocity of about 4 ang.min/s. Here the recording of signals from the observed sources is an isosceles triangle with width of the base about 90 s, which corresponds roughly to 300 instrument readings in each of the examined channels. /4

The abundance of obtained information significantly impairs isolation of weak sources on the background of charged particles. Therefore the task at the first stage is reduced to "rejection" of those segments of information where there are no sources. This work presents a method that makes it possible to isolate the places in the information in which a source is mathematically possible, and after verification of the physical criteria fed into the computer for the presence of a source to issue "suspicious" segments for more detailed analysis.

The physical criteria include:

1. The source in the examined operating pattern of the instrument is recorded in the form of a triangular-shaped impulse on recordings in different energy ranges, whereby the width of the triangle base cannot exceed 140 s, otherwise we have an anomaly, i.e., the passage through the metering devices of the instrument of a stream of charged particles.

2. If the velocity of counting in the maximum impulse in the F1-12 channel is comparable or greater than the corresponding amount in the channels that record the x-ray radiation, for example, in channel F1-4, then "imitation" of the x-ray radiation by the charged particles occurs.

3. In sources of x-ray radiation the velocity of counting in the F1-3 channel must not exceed the value of counting velocity in the F1-2 channel. This follows from the behavior of the curve of recording effectiveness of x-ray quanta [2], as well as from the fact that the sources that possess a sharply rising spectrum in this area until now were not observed. Therefore in such a case we will consider that we again have "imitation" of the source by the charged particles.

2. Information and Algorithm /5

The initial information before feeding into the program is preliminarily averaged for each channel such that the possible source is represented by 5-9 points. In particular, in the examined operating pattern of the instrument the averaging was done for 48 values of the counting velocities. Segments of averaged information, where the instrument readings in more than 15 points in a row exceed 100 i/s are considered anomalous and are nullified by the program.

Since we are interested in the segments which are "suspicious" if but for one of the channels that record x-ray radiation, then further discussions refer only to one channel.

It is assumed that the result of measuring the random process is an additive mixture of the signal and the interference, and due to the discreteness of the measurements can be written in the following form:

$$y_i = f(t_i) + \xi_i = S_i + \xi_i, \quad (1)$$

where $S_i = f(t_i)$--signal and ξ_i--interference.

Since it is known that the signal has a triangular shape, then S_i can be presented in the form:

$$S_i = \begin{cases} 0 & |i - i_0| \geq 2k+1, \\ a\left(1 - \frac{|i-i_0|}{k}\right) & |i - i_0| < 2k+1, \end{cases} \quad (2)$$

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where 2k + 1--width of signal, a--its amplitude, and i_0--time parameter.

It is required that according to the measurements of Y_i the unknown parameters be determined (in our case a, i_0, k). With fixed values of i_0 and k, the parameter a, using the least square method, is found from the expression /6

$$a = \frac{3}{(K+1)(2K+1)} \sum_{j=K+1}^{2K+1} (2K+1-j)(y_i + y_{2(K+1)-j} - 2f_N), \quad /3/$$

where $f_N = (y_1 + y_{2K+1})/2$.

The segments of information for which $a > \sigma_{av}$ are considered "suspicious". Here $\sigma_{av} = \sqrt{D_{av}}$. D_{av}--mean value of dispersion of measurements Y_i with respect to the session. The amount of D_{av} is determined with respect to the background, whereby the background refers to the interval corresponding to 90% of the area of the histogram constructed according to the measurements. In defining D_{cp} the following hypothesis was considered, following from the preliminary analysis of information: $\sum_{j=1}^{M} n_j / N \ll 1$ (M--number of sources in a session, n_j--width of source, N--total number of points) which means that the presence of sources does not noticeably distort the histogram of the background.

The general algorithm looks as follows:

1. With respect to the entire session for the values not exceeding 50 i/s we construct a histogram and define D_{av}.

2. From (3) for the assigned K at each point of the session we define a.

3. The points in which $a > \sigma_{av}$ occurs and the criteria for the presence of a source as "suspicious" are fulfilled, are separated for more detailed analysis.

3. Program and Results of Calculation

The proposed algorithm was realized for the YeS computer in the "Fortran-4" language

The program operates with averaged initial information of the session divided into IN files SDSK(410). In the proposed text of the program, the information counting occurs from the magnetic disk (YeS computer). /7

The SDSK structure:

SDSK(1)--number of points in the file; SDSK(2)--number of session; SDSK(3-5)--date of session. Starting with SDSK(10) the information referring to the given point I of the file is recorded in groups of 10 numbers each ($I \leq 40$):
SDSK(10+(I-1)x10)--Moscow time, for example, 233409--23 hours, 34 minutes, 9 seconds;
SDSK(11-19+(I-1)x10)--values of counting rates in channels F1-1,...,F1-8, F1-12.

The groups of "suspicious" points between which the distance does not exceed K are stored in the file MAP. If this condition is violated, then the given segment together with the K-environs are issued in print (subprogram PAIPER).

In the subprogram MID with respect to the segments of "empty" information the mean values are defined for the counting rates and the mean square deviations σ_j ($j=1,\ldots,8,12$).

As a result of the work the programs are issued in print (for illustration we will limit ourselves to an examination of channels F1-1, 2, 3, 12):

1. Initial information of session:

time	F1-1	F1-2	F1-3	F1-12	Number of point of session
1351	94.6	203.9	583.1	63.3	98
1336	83.6	179.2	487.8	53.9	99
1321	70.5	148.0	404.4	53.4	100
1306	69.3	143.1	348.1	58.3	101
1251	76.3	150.2	334.5	67.1	102
1237	88.1	159.3	334.4	79.0	103
1222	98.6	174.8	321.4	89.2	104
1207	109.6	187.9	318.7	105.8	105
1152	109.3	193.5	321.8	124.8	106
1137	120.3	203.4	304.1	130.1	107
1122	107.2	187.5	265.8	115.4	108
1107	67.7	124.7	192.6	80.2	109

time	Fl-1	Fl-2	Fl-3	Fl-12	Number of point of session
1053	44.4	81.6	143.8	57.1	110
1038	34.6	70.1	117.1	51.3	111
1023	28.6	62.7	106.0	50.4	112
1008	26.1	56.4	85.7	50.0	113
953	20.0	44.2	72.8	43.2	114
938	14.2	31.4	55.7	39.8	115
923	11.2	24.3	41.1	38.2	116
908	9.8	23.8	37.1	38.[illegible]	117

2. The histogram for determining the background, number of points by which the background is defined, and mean value of the background according to the session and σ_j: /8

i/sec	Fl-1	Fl-2	Fl-3	Fl-12
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	1.0	0.0	0.0	0.0
6	0.0	0.0	1.0	0.0
7	42.0	1.0	1.0	0.0
8	65.0	3.0	18.0	0.0
9	13.0	27.0	39.0	0.0
10	20.0	52.0	37.0	0.0
11	9.0	20.0	12.0	1.0
12	2.0	5.0	4.0	0.0
13	2.0	5.0	4.0	0.0
14	1.0	6.0	1.0	0.0
15	1.0	7.0	1.0	1.0
16	0.0	1.0	2.0	0.0
17	1.0	4.0	6.0	7.0
18	0.0	1.0	7.0	21.0
19	0.0	0.0	1.0	31.0
20	1.0	1.0	1.0	32.0
21	0.0	3.0	0.0	7.0
22	0.0	6.0	0.0	6.0
23	0.0	7.0	2.0	4.0
24	1.0	4.0	3.0	0.0
25	0.0	1.0	2.0	2.0
26	1.0	1.0	5.0	0.0
27	0.0	0.0	2.0	5.0
28	0.0	1.0	0.0	5.0

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i/sec	Fl-1	Fl-2	Fl-3	Fl-12
29	2.0	0.0	1.0	1.0
30	0.0	0.0	0.0	2.0
31	0.0	1.0	2.0	3.0
32	0.0	0.0	1.0	1.0
33	0.0	0.0	1.0	0.0
34	0.0	1.0	0.0	1.0
35	1.0	0.0	0.0	2.0
36	0.0	0.0	1.0	1.0
37	0.0	0.0	1.0	3.0
38	0.0	0.0	0.0	1.0
39	0.0	0.0	0.0	5.0
40	0.0	0.0	0.0	3.0
41	0.0	0.0	1.0	0.0
42	0.0	0.0	0.0	2.0
43	1.0	0.0	0.0	3.0
44	1.0	1.0	1.0	1.0
45	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	1.0
47	0.0	0.0	0.0	1.0
48	0.0	0.0	0.0	2.0
49	0.0	0.0	1.0	1.0
50	0.0	0.0	0.0	2.0
	152	127	116	110
	8.1	10.4	9.1	10.2
	0.12E 01	0.17E 01	0.12E 01	0.17E 01

3. The number of "empty" points between the "suspicious" segments, and the mean values of counting rates in them and σ_j ($j=1,2,\ldots,8,12$). /9

The values of amount a in the "suspicious" points (for comparison σ_{av} according to the session is printed over them) and the segment of initial information corresponding to these points together with K-environs:

time	Fl-1	Fl-2	Fl-3	Fl-12	number of points
	3	3	3	3	
	426.0	260.5	28.0	27.5	
	0.18E 03	0.11E 03	0.96E 01	0.12E 02	
	1.2	1.7	1.2	1.7	
234748	822.5	514.0	59.6	45.3	203
234733	1351.0	657.4	78.0	68.8	204
234718	1019.6	550.0	47.0	48.4	205
	23.9	28.4	12.5	21.1	200
	161.0	191.1	25.7	30.0	201
	604.7	384.3	52.1	49.5	202
	1117.0	660.6	83.4	72.5	203
	1470.5	869.5	93.7	96.2	204
	1246.5	683.8	74.6	78.5	205
	740.0	397.2	43.5	47.7	206
	220.0	239.8	15.3	25.1	207
	15.5	20.5	8.5	18.0	208
	12	12	12	12	
	7.0	9.2	10.9	21.7	
	0.74E 01	0.83E 01	0.14E 01	0.13E 01	

From an analysis of the trajectory data it follows that the "suspicious" segment given as an example corresponds to the source SCOX-1 that falls at the given moment in time in the visual field of the instrument--the brightest x-ray source in the celestial sphere.

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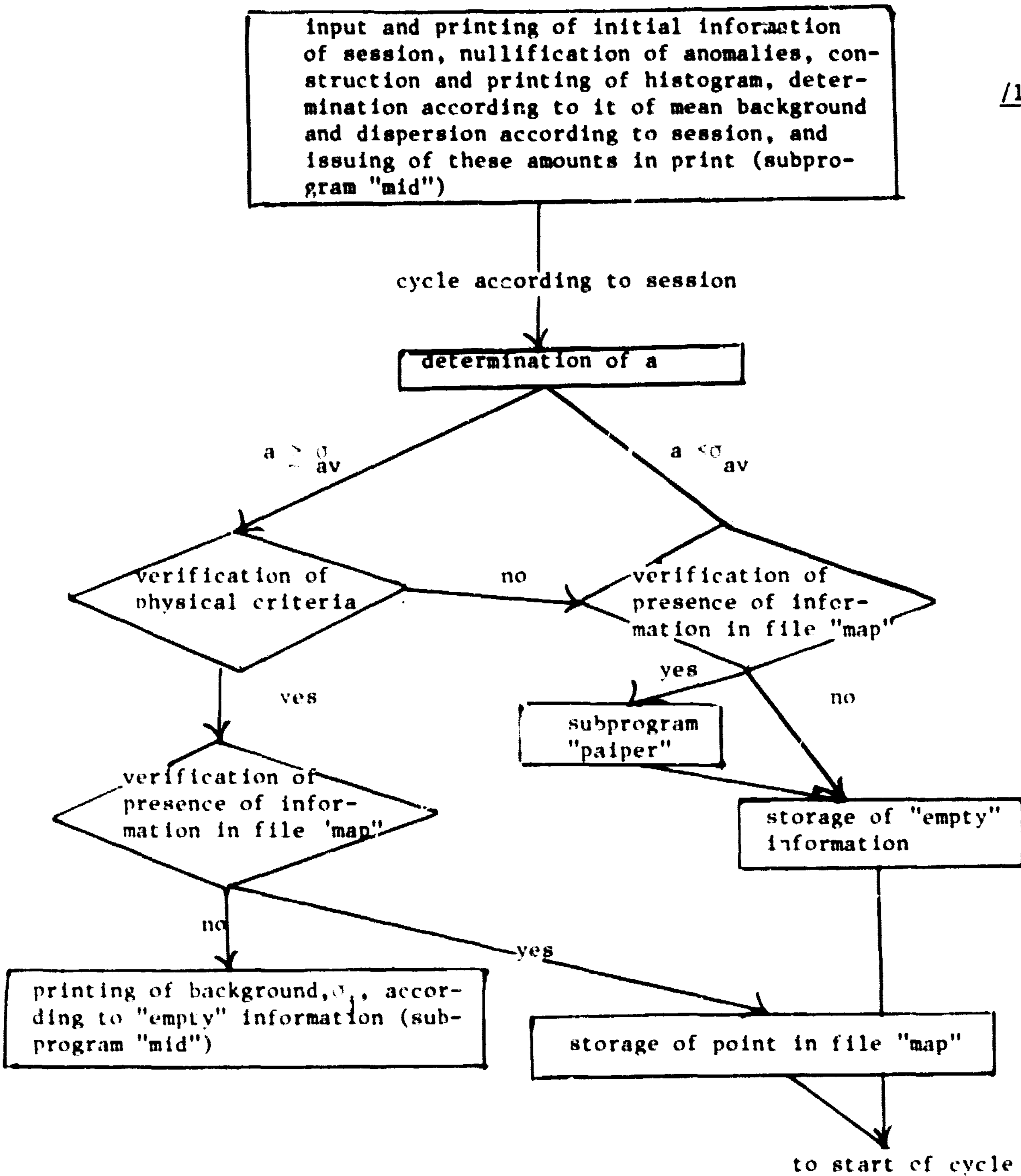
Block Diagram of Program



Text of Program

```
      DIMENSION SDSK(410),A(10),
     1KR(10),MS(10),SG(10),RB(10),
     2SR(10),NS(10),PAR(200,10),
     3TCH(20,10),AZ(200,11),MAP(10,61)
      DEFINE FILE 7(700,1640,L,INR)
      NZ1=10
      NK2=7
      WRITE(3,107)
      WRITE(3,104)

      NPT=0
      DO 10 I=2,10
      NS(I)=0
      DO 10 J=1,61
   10 MAP(I,J)=0
      DO 84 K=1,2
      DO 11 I=1,10
      SG(I)=0.
      A(I)=0.
      KR(I)=0
      DO 11 J=1,30
      PAR(J,I)=0.
   11 CONTINUE
      IN=NZ1
      DO 14 M=1,NK2
      READ(7'IN)(SDSK(I),I=1,410)
      IN=IN+1
      NT=IFIX(SDSK(1))
      DO 14 M1=1,NT
      IF(K-1)69,69,70
   69 NPT=NPT+1
      I1=9+(M1-1)*10+1
      MT=IFIX(SDSK(I1))
      I5=I1+1
      I6=I1+9
      WRITE(3,102)MT,(SDSK(I),I=I5,I6),NPT
      DO 697 I=2,10
      I2=I1+I-1
      I3=6*MAP(I,1)+2
      IF(SDSK(I2)-100)691,694,694
  691 IF(NS(I)-15)692,693,693
  692 MAP(I,I3)=0
      NS(I)=0
      GO TO 697
  693 I4=I3+1
      NS(I)=0
      MAP(I,I4)=NPT-1
```

/11

2

```
      MAP(I,1)=MAP(I,1)+1
      GO TO 697
694   IF(NS(I))695,695,696
695   MAP(I,I3)=NPT
696   NS(I)=NS(I)+1
697   CONTINUE
 70   CONTINUE
      DO 14 I=2,10
      I1=9+(M1-1)*10+I
      S=SDSK(I1)
      IF(S)14,14,12
 12   IF(K-1)71,71,73
 71   J=IFIX(S+0.5)
      IF(J-50)72,72,14
 72   PAR(J,I)=PAR(J,I)+1
      GO TO 14
 73   CONTINUE
      IF(S-RB(I))13,14,14
 13   KR(I)=KR(I)+1
      SG(I)=SG(I)+S*S
      A(I)=A(I)+S
 14   CONTINUE
      IF(K-1)74,74,83
 74   WRITE(3,108)
```

/12

```
      DO 75 J=1,50
 75   WRITE(3,105)J,(PAR(J,I),I=2,10)
      WRITE(3,104)
      DO 82 I=2,10
      I1=1
      DO 77 J=1,50
      IF(PAR(J,I)-PAR(I1,I))77,77,76
 76   I1=J
 77   CONTINUE
      A(I)=PAR(I1,I)
      I2=50
      IF(A(I))81,81,78
 78   DO 80 J=I1,50
      S=PAR(J,I)/A(I)
      IF(S-0.05)79,79,80
 79   I2=J
      GO TO 81
 80   CONTINUE
 81   RB(I)=FLOAT(I2)
 82   CONTINUE
      WRITE(3,109)
      GO TO 84
 83   CALL WID(KR,A,SG)
 84   CONTINUE
```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```
      DO 85 I=2,10
   85 RB(I)=SG(I)
      DO 60 K=5,9,2
      NPT=0
      IN=NZ1
      K2=(K-1)/2
      K1=K2+1
      KT=0
      N1=0
      N2=0
      N3=1
      N4=0
      N5=0
      N6=0
      DO 15 I=2,10
      NS(I)=0
      SG(I)=0.
   15 SR(I)=0.
      DO 30 M=1,NKZ
      READ(7'IN)(SDSK(I),I=1,410)
      IN=IN+1
      DO 19 I=1,6
   19 MS(I)=IFIX(SDSK(I))
      NT=MS(1)
      IF(M-1)20,20,21
   20 MS(1)=K
      WRITE(3,106)
      WRITE(3,100)(MS(I),I=1,3)
      WRITE(3,101)(MS(I),I=4,6)
      WRITE(3,104)
      WRITE(3,107)
      WRITE(3,104)
   21 CONTINUE
      DO 30 M1=1,NT
      NPT=NPT+1
      J1=K-1
      DO 22 J=1,J1
      J2=J+1
      DO 22 I=1,10
   22 TCH(J,I)=TCH(J2,I)                                /13
      I5=10+(M1-1)*10
      TCH(K,1)=SDSK(I5)
      DO 23 I=2,10
      I1=I5+I-1
      IF(MAP(I,1))23,23,221
  221 I3=MAP(I,1)
      DO 225 J1=1,I3
      I4=2+(J1-1)*2
```

```
      IF(NPT-MAP(I,I4))23,222,223
  222 SDSK(I1)=-9.
      GO TO 23
  223 I4=I4+1
      IF(NPT-MAP(I,I4))222,222,225
  225 CONTINUE
   23 TCH(K,I)=SDSK(I1)
      KT=KT+1
      IF(KT-K)50,24,24
   24 KT=KT-1
      DO 26 I=2,10
      KR(I)=0
      DO 26 J=1,K
      IF(TCH(J,I))25,25,26
   25 KR(I)=KR(I)+1
   26 CONTINUE
      DO 31 I=2,10
      IF(KR(I))28,28,27
   27 A(I)=-0.001
      GO TO 31
   28 A(I)=0.
      FON=(TCH(1,I)+TCH(K,I))/2
      DO 29 J=K1,K
      J1=K+1-J
      S=(K-J)*(TCH(J,I)+TCH(J1,I)-2*FON)
   29 A(I)=A(I)+3*S/(K1*K)
      IF(A(I))30,301,301
   30 A(I)=0.
      GO TO 31
  301 J4=0
      DO 304 J3=1,K2
      IF(TCH(J3,I)-TCH(K1,I))304,303,303
  303 J4=J4+1
  304 CONTINUE
      IF(J4-K2)305,30,30
  305 J5=0
      K3=K1+1
      DO 307 J3=K3,K
      IF(TCH(J3,I)-TCH(K1,I))307,306,306
  306 J5=J5+1
  307 CONTINUE
      IF(J5-K2)31,30,30
   31 CONTINUE
      A(1)=TCH(K1,1)
      J=-1
      DO 313 I=2,10
      IF(A(I)-RB(I))313,311,312
  311 J=0
      GO TO 313
  312 J=1
```

```
  313 CONTINUE
      IF(J)33,33,32
   32 S=A(2)
      DO 322 I=2,9
      V=A(I)
      IF(V-S)322,322,321
  321 S=V
  322 CONTINUE
      S1=A(10)
      IF(S-S1)323,323,324
  323 J=0
  324 IF(J)33,33,325
  325 S=A(3)
      S1=A(4)
      IF(S-S1)326,326,33
  326 J=0
   33 IF(J)451,381,37
   34 IF(N1)384,384,35
   35 CALL MID(NS,SR,SG)
      WRITE(3,104)
      N1=0
      DO 36 I=2,10
      NS(I)=0
      SR(I)=0.
   36 SG(I)=0.
      N4=0
      GO TO 384
   37 J=NPT-K1+1
      N6=N6+1
      A2(N6,11)=FLOAT(J)
      DO 371 I=1,10
  371 A2(N6,I)=A(I)
      N3=-K2
      IF(N4)372,372,374
  372 DO 373 J1=1,K2
      I1=NPT-K+J1
      PAR(J1,1)=FLOAT(I1)
      DO 373 I=2,10
  373 PAR(J1,I)=TCH(J1,I)
      N4=1
      N2=K2
  374 N2=N2+1
      J=NPT-K2
      PAR(N2,1)=FLOAT(J)
      DO 38 I=2,10
   38 PAR(N2,I)=TCH(K1,I)
      GO TO 50
  381 IF(N3)382,383,386
  382 N3=N3+1
```


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```
      GO TO 374
  383 IF(N6)452,452,34
  384 WRITE(3,103)(RB(I),I=2,10)
      CALL PAIPER(AZ,PAR,N2,N6)
      WRITE(3,104)
  385 N2=0
      N6=0
      N4=0
      N5=K2
      GO TO 50
  386 IF(N5)41,41,387
  387 N5=N5-1
      GO TO 50
   41 N1=1
      DO 45 I=2,10
      IF(TCH(K,I))45,45,44
   44 NS(I)=NS(I)+1
      SG(I)=SG(I)+TCH(K,I)*TCH(K,I)
      SR(I)=SR(I)+TCH(K,I)
   45 CONTINUE
      GO TO 50
  451 IF(N6)386,386,381
  452 DO 454 I1=1,N2
      DO 454 I=2,10
      IF(PAR(I1,I))454,454,453
  453 NS(I)=NS(I)+1
      SR(I)=SR(I)+PAR(I1,I)
      SG(I)=SG(I)+PAR(I1,I)*PAR(I1,I)
  454 CONTINUE
      N1=1
      GO TO 385
   50 CONTINUE
      IF(N1)52,52,51
   51 CALL MID(NS,SR,SG)
      GO TO 60
   52 CALL PAIPER(AZ,PAR,N2,N6)
   60 CONTINUE
  100 FORMAT(3I5)
  101 FORMAT(3I3)
  102 FORMAT(I7,1X,9F10.1,I7)
  103 FORMAT(8X,9F10.1)
  104 FORMAT(1H )
  105 FORMAT(I7,1X,9F10.1)
  106 FORMAT(////)
  107 FORMAT(1X,'TIME',8X,'FL-1',6X,'FL-2',6X,'FL-3'
     1,6X,'FL-4',6X,'FL-5',6X,'FL-6',6X,'FL-7'
     2,6X,'FL-8',5X,'FL-12',4X,'NPT')
  108 FORMAT(/' histogram to define background         ',/)
  109 FORMAT(/'    *OM:',9F10.1,/)
      DEBUG SUBCHK
      END
```

```
      SUBROUTINE PAIPER(AZ,PAR,N2,N6)
      DIMENSION PAR(200,10),AZ(200,11)
      DO 1 J1=1,N6
      MT=IFIX(AZ(J1,1))
      J=IFIX(AZ(J1,11))
    1 WRITE(3,102)MT,(AZ(J1,I),I=2,10),J
      WRITE(3,104)
      DO 2 I1=1,N2
      J=IFIX(PAR(I1,1))
    2 WRITE(3,106)(PAR(I1,I),I=2,10),J
  106 FORMAT(8X,9F10.1,I7)
  104 FORMAT(1H )
  102 FORMAT(I7,1X,9F10.1,I7)
      RETURN
      END
```

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```
      SUBROUTINE MID(NS,SR,SG)
      DIMENSION NS(1),SR(1),SG(1)
      DO 3 I=2,10
      IF(NS(I)-1)4,1,2
    4 SR(I)=-0.01
    1 SG(I)=0.
      GO TO 3
    2 S=NS(I)*SG(I)-SR(I)*SR(I)
      S=S/(NS(I)*(NS(I)-1))
      SG(I)=SQRT(S)
      SR(I)=SR(I)/NS(I)
    3 CONTINUE
      WRITE(3,105)(NS(I),I=2,10)
      WRITE(3,103)(SR(I),I=2,10)
      WRITE(3,107)(SG(I),I=2,10)
  103 FORMAT(8X,9F10.1)
  107 FORMAT(8X,9E10.2)
  105 FORMAT(8X,9I10)
      RETURN
      END
```

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/17

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