LUNAR LUMINESCENCE MEASUREMENTS

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ABSTRACT

Spectra of lunar sites obtained in June 1983 have been analyzed for residual luminescence using the spectral line depth technique. The results for three sites each at three wavelengths indicate:

SITE	Na D	Ha	K I
Mare Crisium	9.4(±1.1)	8.7(±1.4)	6.8(±1.5)
Kepler	8.1(±1.3)	8.1(±1.1)	9.5(±1.9)
Aristarchus	8.5(±1.7)	8.3(±1.1)	8.0(±1.4)

In each case, the value quoted was based not only on the strong Fraunhofer line in the spectral range covered but also on from 11 to 21 weaker lines within 80 A of the strongest feature.

These data do not support previous observations. The values here given do not indicate a greatly reddened spectrum, and the luminescence spectrum of the mare site is not significantly different from the two young crater sites. These observations cannot be adequately explained by thermal luminescence, theories of direct excitation are also unable to explain the strength of the flux.

Center Research Advisor: Dr. A. E. Potter

INTRODUCTION

Reports of lunar luminescence extend back almost 50 years, yet instrumental limitations have, until recently, made accurate values for the luminescent flux(as a percent of reflected light) difficult or impossible to obtain. Nevertheless, these early measurements did demonstrate the existance of the phenomenon. The early measurements showed variability both from site to site and with phase angle at a given site. Both direct excitation and thermal luminescence have been proposed.

APPROACH

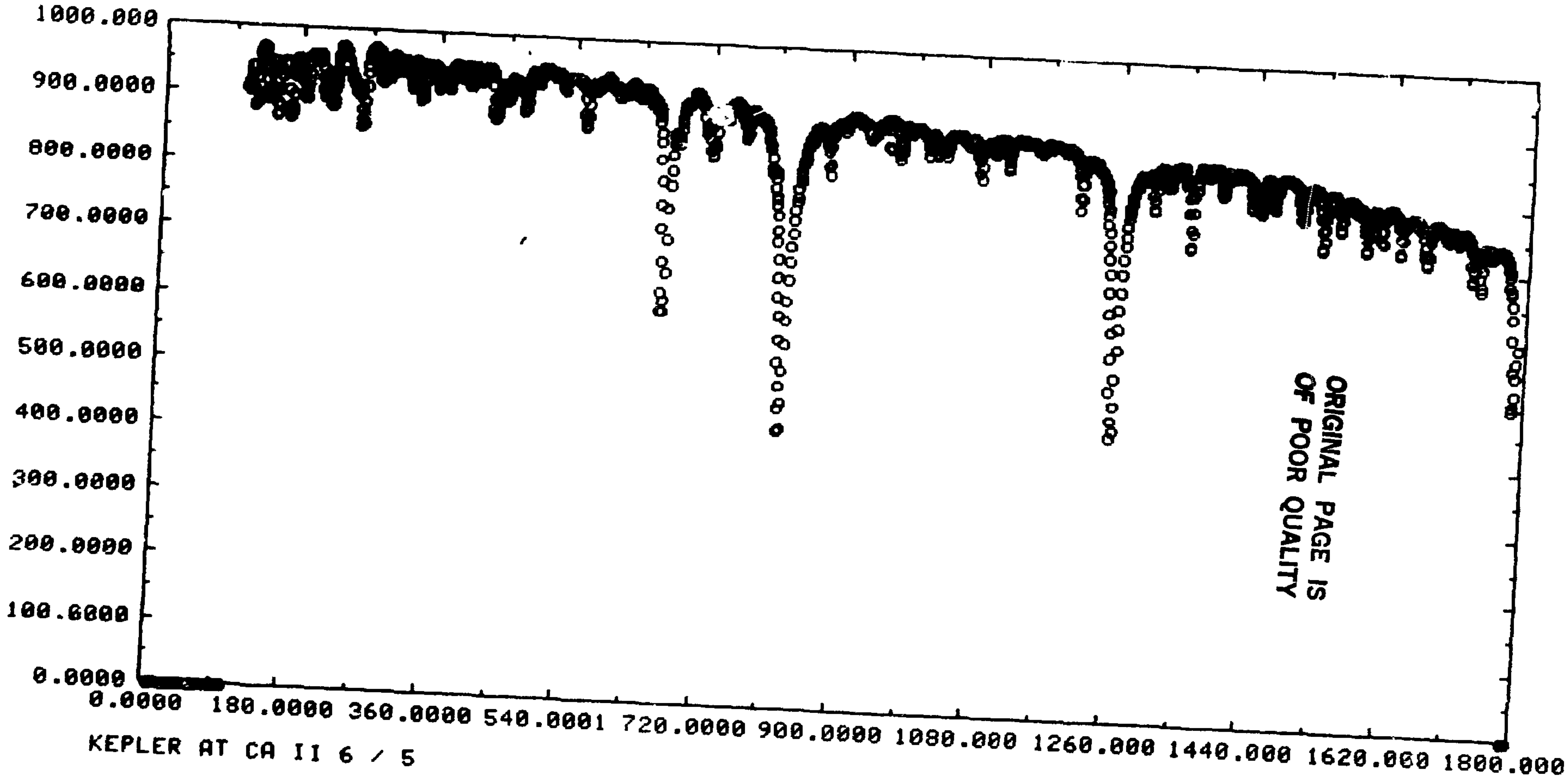
Recently, the application of multi-element arrays to observational astronomy has made made accurate determinations of luminescence possible. Accordingly, the coude spectrograph of the 2.7 m telescope at McDonald Observatory was recently used to obtain observations of selected sites at a number of strong Fraunhofer lines. These measurements require a solar spectrum obtained with the same spectrograph for interpretation. If there is a non-reflective component in the observed light from a lunar site then the apparent depths of the Fraunhofer lines in the lunar spectrum plotted against the Fraunhofer line-depths for the corresponding line in the solar spectrum should kave a positive intercept. Figure 1 shows the raw data, and figure 2 shows a plot of the relative line depths as discribed above. Attachments 1 and 2 are computer programs which take the measured relative line depths (stored on disk), determine a least-squares fit, do some elementary statistics, and calculate the residuals in form suitable for plotting. Figure 3 illustrates the quality of the fit.

RESULTS

On the three sites whose data have been measured, the luminous fluxes fall in the range 6-10 percent of reflected light. the most significant results are that (1) the luminescence of Aristarchus is not stronger than the other two sites and (2) that the luminescence is not increasing as a percent of reflected light in the red as reported previously in the literature.

TABLE 1

SITE	Na D	Ha	K I
Mare Crisium	9.4 (±1.1)	8.7 (±1.4)	6.8 (±1.5)
Kepler	8.1 (±1.3)	8.1 (±1.1)	9.5 (±1.9)
Aristarchus	8.5 (±1.7)	8.3 (±1.1)	8.0 (±1.4)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700.0000
600.0000
500.0000
400.0000
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540.0001
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900.0000
1080.000
1260.000
1440.000
1620.000
1800.000
KEPLER AT CA II 6 / 5
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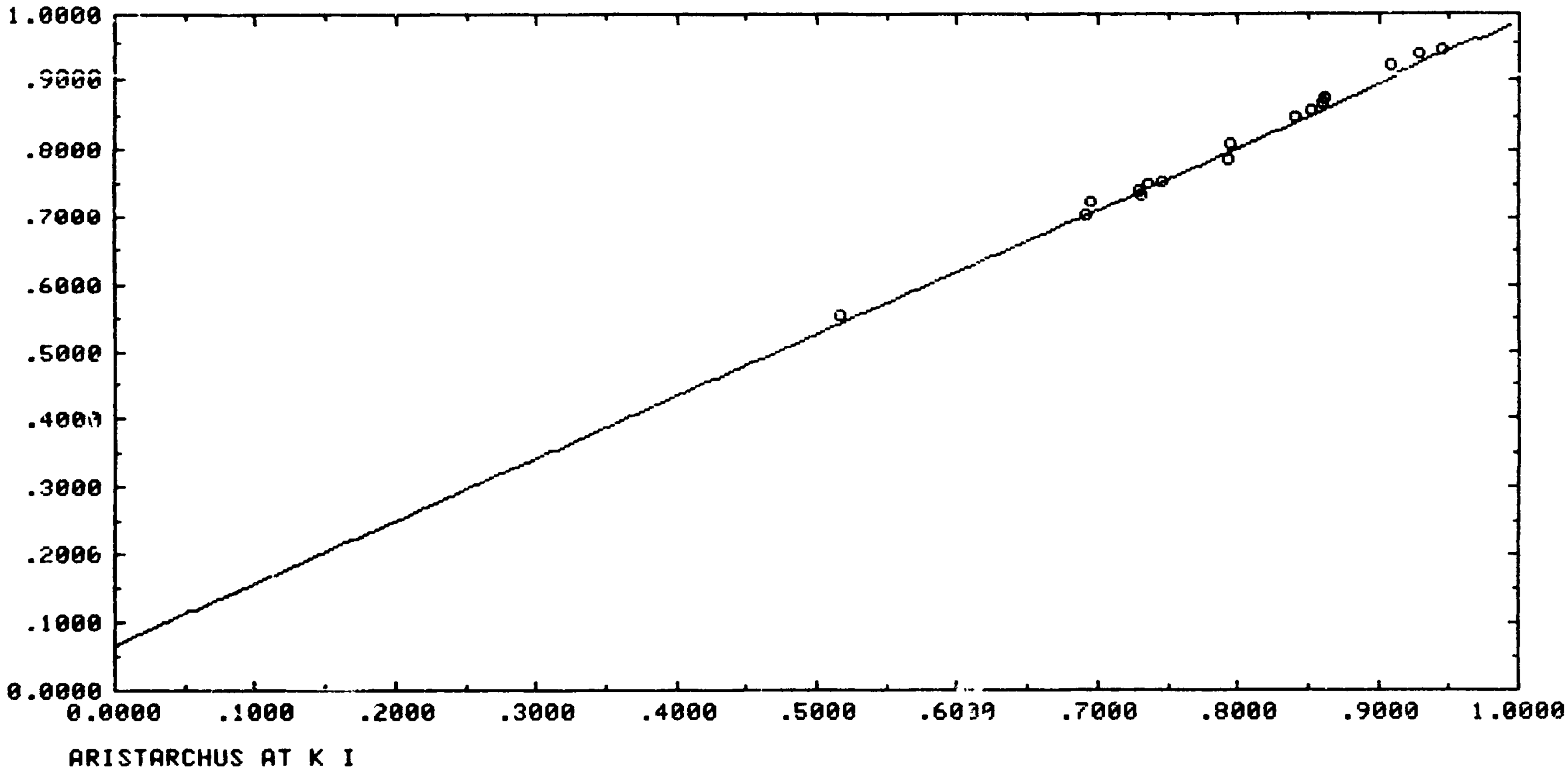
FIGURE 1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.8000
.7000
.6000
.5000
.4000
.3000
.2000
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0.0000
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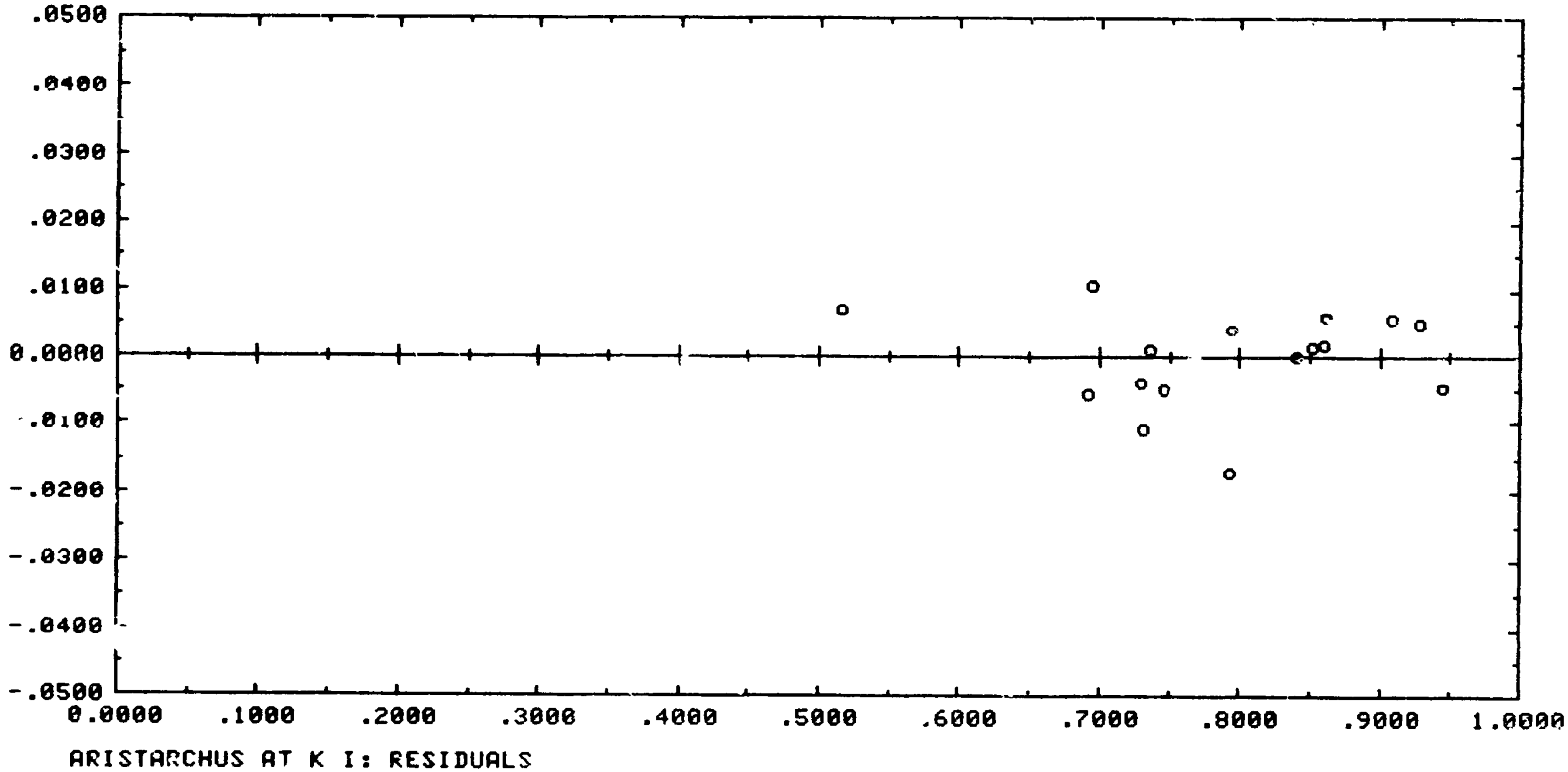
.3000
.4000
.5000
.6000
.7000
.8000
.9000
1.0000
ARISTARCHUS AT K I

FIGURE 2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-.0200
-.0300
-.0400
-.0500
0.0000
.1000
.2000
.3000
.4000
.5000
.6000
.7000
.8000
.9000
1.0000
ARISTARCHUS AT K I: RESIDUALS

FIGURE 3

ATTACHMENT 1

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```
C                       PROGRAM LUNF11.FOR
C
C         THIS PROGRAM WILL READ DIGITIZER FILES SPECIALLY CREATED FOR IT.
C       IN PARTICULAR, THESE FILES ARE:
C         1. EACH FOR A NUMBER OF FRAUNHOFER LINES IN A GIVEN WINDOW.
C         2. DATA IN GROUPS OF 3S--CON,LINE CTR,CON.
C         3. FILES READ ARE CREATED BY DIGITIZER.
C         IN ADDITION, THE PROGRAM WILL CREATE A DATA FILE WITH THE RESULTING
C       RATIOS IN IT. IT WILL  CALCULATE THE LEAST SQUARES
C       FIT SLOPE AND INTERCEPT FOR THE DATA SET AND CREATE A DATA FILE.
C
C                               --BUT--
C
C       WRITE DOWN THE FITTING TERMS.
C               DONE  15/JUL/83 THM
C               MODIFIED 20/JUL/83//MODIFIED 21/JUL/83
C
C                       SECTION I
C                 INITIALIZATION
C
        CHARACTER*64        LINEM,LINES
        CHARACTER*30        MFILE,SFILE,RFILE
        DIMENSION YMN(200),YSN(200),RATM(100),RATS(100)
        INTEGER NMAXM,NMAXS
C
C                       SECTION II
C                 READ TWO DIGITIZER FILES
C
        WRITE(6,*) ' ENTER MOON FILE NAME AS XXX.N;M ' !LIKE DIR LIST
10      FORMAT(A64)                             !DIGITIZER MOONFILE
        READ(5,10)MFILE
        OPEN(UNIT=4,FILE=MFILE,STATUS='OLD',READONLY)
                DO 50 I=1,200                   !READS Y'S OUT OF LINE
                READ(4,10,END=50) LINEM
                DECODE(7,20,LINEM(51:58)) YMN(I)
20              FORMAT(F10.1)
                NMAXM=I
50              CONTINUE
        WRITE(6,*) ' ENTER SUNFILE AS XXX.N;M ' !DIGITIZER SUNFILE
        READ(5,10) SFILE
        OPEN(UNIT=4,FILE=SFILE STATUS='OLD',READONLY)
                DO 100 J=1,200                  !Y'S FOR SUN
                READ(4,10,END=100) LINES
                DECODE(7,20,LINES(51:58)) YSN(J)
                NMAXS=J
100             CONTINUE
        IF(NMAXM.EQ.NMAXS) GO TO 150
        WRITE(6,*) ' FILES DO NOT HAVE SAME NO. OF LINES '
        GO TO 999
150     IF((MOD(NMAXM,3)).EQ.0) GO TO 200
        WRITE(6,*) ' NO OF LINES NOT MULTIPLE OF THREE '
        GO TO 999
C
C                       SECTION III
C                 HERE THE DEPTH TO CONTINUUM RATIOS ARE CALCULATED
C
200             LIMMS=NMAXM-1
                IRES=1
                DO 250 K=1,LIMMS,3
                RATM(IRES)=((YMN(K+1))/(((YMN(K))+(YMN(K+2)))/2.0)) ! M DEPTH
                RATS(IRES)=((YSN(K+1))/(((YSN(K))+(YSN(K+2)))/2.0)) ! S DEPTH
```

```
                IRES =IRES+1
250             CONTINUE
C
C                       SECTION IIII
C               WRITES A DATA FILE WITH THE LUNAR AND SOLAR RATIOS PAIRED
C
          WRITE(6,*) ' LUNAR AND SOLAR RATIOS '
          IRES=IRES-1
          WRITE(5,300)(RATM(N),RATS(N),N=1,IRES)
300       FORMAT(2X,2F15.5)
                WRITE(6,*) ' MAKE NAME OF RATIO FILE AS XXXX.DAT '
                READ(5,10) RFILE
                OPEN(UNIT=10,FILE=RFILE,STATUS='NEW')
                WRITE(10,300)(RATM(N),RATS(N),N=1,IRES)
C
C                       SECTION V
C               LEAST SQUARES CALCULATION
C
                        SMXS=0  !SUM OF RATM SQUARED TERMS      ZEROED
                        SMX=0   !SUM OF RATS VALUES             ZEROED
                        SMY=0   !SUM OF RATM VALUES             ZEROED
                        SMXYS=0 !SUM OF CROSS TERMS             ZEROED
                DO 350 ICNT=1,IRES
                SMX=RATS(ICNT)+SMX      !DOING THE SUMS
                SMXYS=((RATM(ICNT))*(RATS(ICNT)))+SMXYS
                SMXS=((RATS(ICNT))**2)+SMXS
                SMY=(RATM(ICNT))+SMY
350             CONTINUE
                        DELLS=(IRES*(SMXS))-(SMX**2)
                        AFIT=((SMXS*SMY)-(SMX*SMXYS))/DELLS ! SLOPE
                        BFIT=((IRES*SMXYS)-(SMX*SMY))/DELLS ! INTERCEPT
                WRITE(6,*) ' INTERCEPT AND SLOPE ARE '
                WRITE(5,425) AFIT,BFIT
425             FORMAT(2X,F15.5,2X,F15.5)
                        XLUMB=(AFIT*100)/(1-AFIT)
                WRITE(6,*) ' PERCENT LUMINENCE IS '
                WRITE(5,450) XLUMB
450             FORMAT(5X,F15.5)
999       CONTINUE
          STOP
          END
```

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ATTACHMENT 2

```
C                         PROGRAM LUMSTAT.FOR
C
C      THIS PROGRAM WILL READ DIGITIZER FILES SPECIALLY CREATED FOR LUMFIT
C     AND DO AN EXTENDED STATISTICAL ANALYSIS OF THEM. IT DOES, INADDITION
C     THE A AND B COEFCIENTS FOR THE LEAST SQUARES FIT,THE FOLLOWING:
C       1. A GOODNESS OF FIT ESTIMATOR FOR A AND B
C       2. THE SUMI OF THE SUM OF THE SQUARES TYPE CALCULATION.
C       3. THE DIFFERENCE DELTA SUB I FOR ALL THE DATA POINTS.
C      IN ADDITION, THE PROGRAM WILL CREATE A DATA FILE WHICH CONTAINS THE
C     DIFFERENCES AND THEIR SQUARES FOR FURTHER CONSIDERATION.
C      THE SOURCE FOR THE EQUATIONS CONTAINED HEREIN IS
C
C              DATA REDUCTION AND ERROR ANALYSIS FOR THE
C                        PHYSICAL SCIENCES
C                              BY
C                         P. R. BEVINGTON
C                  ( SEE CHAPTER SIX IN PARTICULAR)
C
C     ONLY THE DIFFERENCES ARE SAVED AS A DATA FILE.
C
C                       DONE BY TOM MORGAN
C              CREATED 25/JULY/83/
C              MODIFIED 26/JUL/83//27JULY/83//28/JUL/83//
C
C
C                      SECTION I
C              INITIALIZATION
C
       CHARACTER*1         XAFF
       CHARACTER*64        LINEM,LINES
       CHARACTER*30        MFILE,SFILE,RFILE
       DIMENSION YMN(200),YSN(200),RATM(100),RATS(100)
       DIMENSION DFLAM(100),DFLAMS(100)
       INTEGER NMAXM,NMAXS
C
C                      SECTION II
C              READ TWO DIGITIZER FILES
C
       WRITE(6,*) ' ENTER MOON FILE NAME AS XXX.N;M ' !LIKE DIR LIST
10     FORMAT(A64)                              !DIGITIZER MOONFILE
       READ(5,10)MFILE
       OPEN(UNIT=4,FILE=MFILE,STATUS='OLD',READONLY)
               DO 50 I=1,200                    !READS Y'S OUT OF LINE
               READ(4,10,END=50) LINEM
               DECODE(7,20,LINEM(51:58)) YMN(I)
20             FORMAT(F10.1)
               NMAXM=I
50             CONTINUE
       WRITE(6,*) ' ENTER SUNFILE AS XXX.N;M ' !DIGITIZER SUNFILE
       READ(5,10) SFILE
       OPEN(UNIT=4,FILE=SFILE,STATUS='OLD',READONLY)
               DO 100 J=1,200                   !Y'S FOR SUN
               READ(4,10,END=100) LINES
               DECODE(7,20,LINES(51:58)) YSN(J)
               NMAXS=J
100            CONTINUE
       IF(NMAXM.EQ.NMAXS) GO TO 150
       WRITE(6,*) ' FILES DO NOT HAVE SAME NO. OF LINES '
       GO TO 999
150    IF((MOD(NMAXM,3)).EQ.0) GO TO 200
       WRITE(6,*) ' NO OF LINES NOT MULTIPLE OF THREE '
```

```
      GO TU 999
C
C              SECTION III
C        HERE THE DEPTH TU CONTINUUM RATIOS ARE CALCULATED
C
200      LIMMS=NMAXN-1
         IRES=1
         DO 250 K=1,LIMMS,3
         RATM(IRES)=((YMN(K+1))/(((YMN(K))+(YMN(K+2)))/2.0)) ! M DEPTH
         RATS(IRES)=((YSN(K+1))/(((YSN(K))+(YSN(K+2)))/2.0)) ! S DEPTH
         IRES =IRES+1
250      CONTINUE
C
C              SECTION IIII
C        LEAS* SQUARES CALCUATION OF LUMINANCE
C
               IRES=IRES-1
               SMXS=0  !SUM OF RATM SQUARED TERMS       ZEROED
               SMX=0   !SUM OF RATS VALUES              ZEROED
               SMY=0   !SUM OF RATM VALUES              ZEROED
               SMXYS=0 !SUM OF CROSS TERMS              ZEROED
         DO 350 ICNT=1,IRES
         SMX=RATS(ICNT)+SMX      !DOING THE SUMS
         SMXYS=((RATM(ICNT))*(RATS(ICNT)))+SMXYS
         SMXS=((RATS(ICNT))**2)+SMXS
         SMY=(RATM(ICNT))+SMY
350      CONTINUE
               DELLS=(IRES*(SMXS))-(SMX**2)
               AFIT=((SMXS*SMY)-(SMX*SMXYS))/DELLS ! INTERCEPT
               BFIT=((IRES*SMXYS)-(SMX*SMY))/DELLS ! SLOPE
         WRITE(6,*) ' INTERCEPT AND SLOPE ARE '
         WRITE(5,425) AFIT,BFIT
425      FORMAT(2X,F15.5,2X,F15.5)
               XLUMA=(AFIT*100)/(1-AFIT)
               XLUMB=((1-BFIT)/BFIT)*100
         WRITE(6,*) ' PERCENT LUMINENCE FROM A AND B IS RESPECTIVELY '
         WRITE(5,450) XLUMA,XLUMB
450      FORMAT(2(5X,F15.5))
C
C              SECTION V
C        CALCULATING THE DIFFERENCES THEIR SQUARES AND SIGMAS
C
               VARS=0              ! ZEROES VARIANCE
               SLAM=0              ! ZEROES RUNNING SUM
               DO 500 IS=1,IRES    ! DOES LUM AND VAR CAL
               DFLAM(IS)=RATM(IS)-(AFIT+BFIT*(RATS(IS)))
               DFLAMS(IS)=(DFLAM(IS))**2
               VARS=DFLAMS(IS)+VARS
500            CONTINUE
               VARS=VARS/(IRES-2)
               SIGA=(VARS*SMXS)/DELLS
               SIGB=(IRES*VARS)/DELLS
               SSIGA=SQRT(SIGA)
               SSIGB=SQRT(SIGB)
               SVARS=SQRT(VARS)
         WRITE(6,*) ' SIGMA A        SIGMA B        SIGMA Y IRES   '
         WRITE(5,525)SSIGA,SSIGB,SVARS,IRES
525      FORMAT(2X,F10.5,2X,F10.5,2X,F10.5,2X,I3)
         WRITE(6,*) ' PAUSE HIT ANY KEY WHEN YOUR READY '
         READ(5,750)XAFF
         WRITE(6,*) ' TABLE OF DEVIATIONS '
```

```
              WRITE(5,725)(IPT,DFLAM(IPT),DFLAMS(IPT),IPT=1,IRES)
725           FORMAT(2X,I3,2X,F10.5,2X,F10.5)
750     FORMAT(A1)
        WRITE(6,*) ' NAME THE DELTA 1 FILE AS ZZZZ.CAT '
        READ(5,10)RFILE
        OPEN(UNIT=10,FILE=RFILE,STATUS='NEW')
        WRITE(10,775)(DFLAM(LDIF),RATS(LDIF),LDIF=1,IRES)
775     FORMAT(2X,2F15.10)
999     CONTINUE
        STOP
        END
```