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:

<table>
<thead>
<tr>
<th>SITE</th>
<th>Na D</th>
<th>Ha</th>
<th>K I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mare Crisium</td>
<td>9.4(±1.1)</td>
<td>8.7(±1.4)</td>
<td>6.8(±1.5)</td>
</tr>
<tr>
<td>Kepler</td>
<td>8.1(±1.3)</td>
<td>8.1(±1.1)</td>
<td>9.5(±1.9)</td>
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<tr>
<td>Aristarchus</td>
<td>8.5(±1.7)</td>
<td>8.3(±1.1)</td>
<td>8.0(±1.4)</td>
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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 Å 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

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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 existence 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 have a positive intercept. Figure 1 shows the raw data, and figure 2 shows a plot of the relative line depths as described 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.

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ATTACHMENT 1

PROGRAM LUNFIL.FOR

THIS PROGRAM WILL READ DIGITIZER FILES SPECIALLY CREATED FOR IT.

IN PARTICULAR, THESE FILES ARE:
1. EACH FOR A NUMBER OF PHAUMHDLER LINES IN A GIVEN WINDOW.
2. DATA IN GROUPS IN 38=COMMON LINE CIR,CUM.
3. FILES READ ARE CREATED BY DIGITIZR.

IN ADDITION, THE PROGRAM WILL CREATE A DATA FILE WITH THE RESULTING
RATIOS IN IT. IT WILL CALCULATE THE LEAST SQUARES
FIT SLOPE AND INTERCEPT FOR THE DATA SET AND CREATE A DATA FILE.

--but--

WRITE DOWN THE FITTING TERMS.

DUE 15/JUL/83 THM
MODIFIED 20/JUL/83//MODIFIED 21/JUL/83

SECTION I
INITIALIZATION

CHARACTER*64 LINEM,LINES
CHARACTER*30 MFILE, SFILE, PFILE
DIMENSION IMN(200), ISN(200), HAT(100), HATS(100)
INTEGER MMAX, NMAX

SECTION II
READ TWO DIGITIZER FILES

WRITE(6,*),' ENTRUK MOON FILE NAME AS XXX.N;M ' ILIKE DIM LIST
FORMAT(AS64) DIGITIZER MOONFILE
READ(5,10) PFILE
OPEN(UNIT=4,FILE=MFIL,STATUS='OLD',READONLY)
DO 50 I=1,200 ;READS Y'S OUT OF LINE
READ(4,10,END=50) LINEM
DECIDE(7,20, LineM(51:58)) YMN(I)
FORMAT(F10,1)
MAXIM=1

CONTINUE

WRITE(6,*),' ENTRUK SUNFILE NAME AS XXX.N;M ' IDIGITIZER SUNFILE
READ(5,10) SFILE
OPEN(UNIT=4,FILE=SFIL,STATUS='OLD',READONLY)
DO 100 J=1,200 ;IT'S FOR SUN
READ(4,10,END=100) LINES
DECIDE(7,20, Lines(51:58)) YSN(J)
MAXS=J
CONTINUE

IF(MMAX.EQ.NMAX) GO TO 150
WRITE(6,*),' FILES DO NOT HAVE SAME NO. OF LINES ' GU TO 999

150 IF((MOD(NMAX,3)).EQ.0) GU TO 200
WRITE(6,*),' NO OF LINES NOT MULTIPLE OF THREE ' GU TO 999

SECTION III

HERE THE DEPTH TO CONTINUUM RATIOS ARE CALCULATED

200 LINMS=MMAX-1
INE=1
DO 250 K=1,LINMS,3
HATM(INKS)=(YMN(K+1))/(((YMN(K)+YMN(K+2))/2.0)) 1 M DEPTH
HATS(INKS)=(YSN(K+1))/(((YSN(K)+YSN(K+2))/2.0)) 1 S DEPTH
IRLS = 1
CONTINUE

SECTION III

WRITE(0,*) ' LUNAR AND SOLAR RADIUS'
IRLS=IRLS-1
WRITE(5,400)(RATM(N),RATS(N),N=1,IRLS)

WRITE(0,*) ' MAKE NAME OF RADIUS FILE AS XXXX.DAT'
REAU(5,10) NFILE
OPEN(UNIT=10,FILE=NFILE,STATUS='NEW')
WRITE(10,300)(RATM(N),RATS(N),N=1,IRLS)

SECTION V

LEAST SQUARES CALCULATION

SMX=0  SUM OF RATS VALUES ZEROED
SMY=0  SUM OF RATM VALUES ZEROED
SMXS=0 SUM OF CROSS TERMS ZEROED
DO 350 ICNT=1,IRLS
     SUM=HATI(ICNT)+SMX
     SMX=(RATM(ICNT)+RATI(ICNT)+SMI)
     SMY=(RATI(ICNT)+SMI)
     CONTINUE

DELLS=(IRLS*(SMXS)-(SMX*2))/DELLS ! SLOPE
BFIT=((IRLS*SMX)-(SMX*SMYS))/DELLS ! INTERCEPT

WRITE(6,*) ' INTERCEPT AND SLOPE ARE '
WRITE(5,425) AFIT,BFIT

CONTINUE

999 CONTINUE
STOP
END

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ATTACHMENT 2

PROGRAM LUMSTAT.FOR

THIS PROGRAM WILL READ DIGITIZER FILES SPECIALLY CREATED FOR LUMFIT
AND DO AN EXTENDED STATISTICAL ANALYSIS OF THEM. IT DOES, IN ADDITION
THE A AND B COEFFICIENTS FOR THE LEAST SQUARES FIT, THE FOLLOWING:
1. A GOODNESS OF FIT ESTIMATE FOR A AND B
2. THE SUM OF THE SUM OF THE SQUARES FOR CALCULATION.
3. THE DIFFERENCE DELTA SUM 1 FOR ALL THE DATA POINTS.

IN ADDITION, THE PROGRAM WILL CREATE A DATA FILE WHICH CONTAINS THE
DIFFERENCES AND THEIR SQUARES FOR FURTHER CONSIDERATION.
THE SOURCE FOR THE EQUATIONS CONTAINED HEREIN IS

DATA REDUCTION AND ERROR ANALYSIS FOR THE
PHYSICAL SCIENCES
BY
P. W. REVENING
(SEE CHAPTER SIX IN PARTICULAR)

ONLY THE DIFFERENCES ARE SAVED AS A DATA FILE.

DONE BY TOM MORGAN
CREATED 25/ JULY/83/
MODIFIED 26/ JULY/83//27JULY/83//2W/JUL/83//

SECTION I
INITIALIZE

CHARACTER*1 AAFF
CHARACTER*4 LINEM, LINES
CHARACTER*4 MFILE, SFILE, HFILE
DIMENSION YMN(200), YSN(200), RAT(100), RATS(100)
DIMENSION DFLAM(100), DFLAMS(100)
INTEGER NMAX, NMAX1

SECTION II
READ TWO DIGITIZER FILES

WRITE(6,*) ' ENTER MCF FILE NAME AS XXX.MCF ' ILIKE DIR LIST
FORMAT((A4)) 'IDIGITIZER MCF MFILE
READ(5,10) MFILE
OPEN(UNIT=4, FILE=MFILE, STATUS='OLD', READONLY)
DO 50 I=1, 200
READ(4,10, END=50) LINEM
DECIDE(7, 20, LINEM(51:58)) YMN(I)
FORMAT((I10, I)) NMAX1
CONTINUE

WRITE(6,*) ' ENTER SUNFILE AS XXX.SUN ' IDIGITIZER SUNFILE
READ(5, 10) SFILE
OPEN(UNIT=4, FILE=SFILE, STATUS='OLD', READONLY)
DO 100 J=1, 200
READ(4, 10, END=100) LINES
DECIDE(7, 20, LINES(51:58)) YSN(J)
NMAX=J
CONTINUE

IF(NMAX.EQ.0) GO TO 150
WRITE(6,*) ' FILES DO NOT HAVE SAME NO. OF LINES ' GO TO 999
150 IF((MOD(NMAX, 3)).EQ.0) GO TO 200
WRITE(6,*) ' NO OF LINES NOT MULTIPLE OF THREE '

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GO TO 999

SECTION III
HERE THE DEPTH TO CONTINUUM RATIUS ARE CALCULATED

LINES=MAXN+1
IMES=1
UJ 250 KM1,LINES,) 
MATH(INES)=(1(YMM(K+1))/(((YMM(K)+(YMM(K+2))/2,0)) ! M DEPTH 
HRZ(INES)=(1(YMM(K+1))/(((YMM(K)+(YMM(K+2))/2,0)) ! S DEPTH 
IMES=INES+1
CONTINUE

SECTION III
LEAST SQUARES CALCULATION OF LUMINANCE

IMES=IMES+1
SMXS=0 SUM OF MATH SQUARED TERMS ZEREOED
SMX=0 SUM OF MATH VALUES ZEREOED
SMY=0 SUM OF MATH VALUES ZEREOED
SMYS=0 SUM OF CROSS TERMS ZEREOED
DO LINES ICNT=1,INES 
SMX=SMX((MATH(ICNT)*/(MATH(ICNT)))+SMX 
SMY=SMY((MATH(ICNT)))#2)+SMY 
SURF=(MATH(ICNT))*SMY 
CONTINUE

Dells=(IMES*(SMX))-(SMX*2)
AFIT=((SMX*SMY)-(SMX*SMYS))/Dells I INTERCEPT 
BFIIT=((IMES*SMXS)-(SMX*SMYS))/Dells I SLOPE 
WRITE(b,* ) ' INTERCEPT AND SLOPE ARE ' 
WRITE(5,425) AFIT,BFIIT 
FORMAT(2X,F15.5,2X,F15.5) 
XLOMA=(AFIT100)/(1-AFIT) 
XLOMB=(1-BFIIT)/BFIIT100 
WRITE(b,* ) ' PERCENT LUMINANCE FROM A AND B IS RESPECTIVELY ' 
WRITE(5,450) XLOMA,XLOMB 
FORMAT(2X,F15.5)

SECTION V
CALCULATING THE DIFFERENCES THEIR SQUARES AND SIGMAS

VARS=0 I ZEREOES VARIANCE 
SLAM=0 I ZEREOES RUNNING SUM 
DO 525 IS=1,IMES I DOES LUM AND VAR CAL 
DFLAM(IS)=MATH(IS)-(AFIT+BFIT*(PAIS(IS))) 
DFLAM(IS)=(DFLAM(IS))#2 
VARS=DFLAM(IS)+VARS 
CONTINUE

VARS=VARS/(IMES-2) 
SIGA=(VARS&SMAS)/Dells 
SIGB=(VARS&SMBS)/Dells 
SIGA=SIGA#SIGA 
SIGB=SIGA#SIGA 
VARS=SQR(T(VARS)

WRITE(b,* ) ' SIGMA A SIGMA B SIGMA Y IRES ' 
WRITE(5,525) SIGA,SIGB,VARS,IMES 
FORMAT(2X,F10.5,2X,F10.5,2X,F10.5,2X,F10.5,2X) 
WRITE(b,* ) ' WAUSE HIT ANY KEY WHEN YOU READY ' 
READ(5,750)XAFF 
WRITE(b,* ) ' TABLE OF DEVIATIONS ' 

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```
*WITE(5,725)(1PT,DFLAM(IPT),DI LAYS(IPT),IPT=1,INES)
  FUMAT(2A,13,2A,FIU.5,2X,10,5)
725
750  FUMAT(AI)
    WITE(0,*) ' NAME THE DELTA 1 FILE AS ZZZZ.DAT '
    READ(5,10)IHFE
    OPEn(UNIT=10,FILE=IHFE,STATUS='NEW')
    WITE(10,775)(DFLAN(LDIF),MAT5(LDIF),LDIF=1,INES)
775
999  CONTINUE
    STOP
    END
```