THE ASTRONOMICAL TURBIDITY PROJECT

E. Farkas

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Abstract

The origin and history of a co-operative research project planned to be carried out jointly by New Zealand Astronomical Observatories and the New Zealand Meteorological Service to monitor atmospheric turbidity by solar and stellar extinction measurements on a routine long term basis is described.

The main principles involved in computation of turbidity parameters from measurements made at selected New Zealand Astronomical Observatories are discussed.

Data logging samples and listing of a computer analysis program developed under contract by the Physics Department, University of Otago are attached and a summary of the astronomical turbidity data and analysis available up to the termination of the project is given.

1. Introduction

During 1975-79, the haze scattering characteristics of the atmosphere were studied from a short period of direct measurements with VOLZ solar photometers (Farkas, 1978) and also by indirect calculations using long period Dobson spectrophotometer measurements (Farkas, 1976).

Both studies pointed out the need for dedicated observations on a regular basis with improved instrumentation if turbidity monitoring was to be pursued by the Meteorological Service in the future. This led to the commencement of establishing a modest turbidity observation network in New Zealand, using solar photometry (Farkas, 1980).

The desire to find other independent observations possibly existing in the region which could be compared with results of the above analysis led to the discovery, that some astronomical observatories in New Zealand had the equipment and were already making photometric stellar irradiance observations suitable for the calculation of turbidity.

Following our inquiries, some of the existing data at the Auckland Astronomical Observatory were evaluated by G.W. Christie and results covering the 1970-72 period comprising 32 stellar extinction values were sent to us.

A plot of the extinction coefficients calculated from observations on one of the three filters of the photometric system in use at the Auckland Observatory (Johnson UBV, see Section 2), namely at a mean wavelength of .556 µm is given in Fig. 1. Values of the extinction are given in stellar magnitudes per airmass. These coefficients were not directly comparable to turbidity parameters calculated from the solar photometric data, and the discontinuous nature and relatively large uncertainties (error bars) evident in the stellar data prevented meaningful comparisons to be made with the trends found from the Dobson observations.

It was thought worthwhile however to try to obtain stellar turbidity measurements in the future, which were hoped to be made compatible with, and could complement, results of observations from the solar turbidity network.

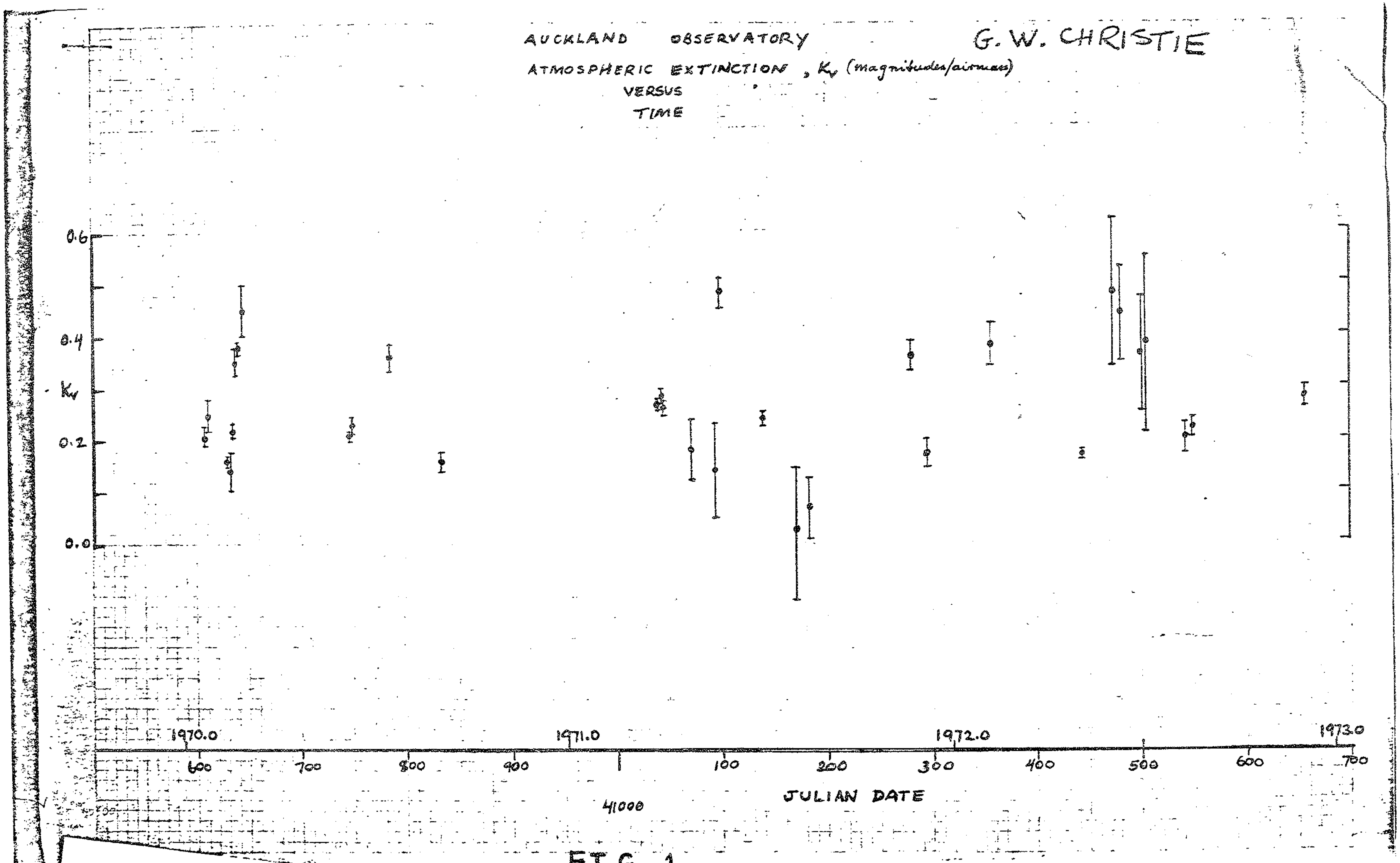
AUCKLAND OBSERVATORY
ATMOSPHERIC EXTINCTION , Kv (magnitudes/airmass)
VERSUS
TIME
G.W. CHRISTIE
0.6
0.4
Kv
0.2
0.0
1970.0
1971.0
1972.0
1973.0
600
700
800
900
100
200
300
400
500
600
700
41000
JULIAN DATE

FIG. 1

Professor P.J. Edwards from the Physics Department of the University of Otago put up a proposal in 1976 and consequently obtained a research contract from the New Zealand Meteorological Service for the establishment of the routine collection and the evaluation method of astronomical data from all Observatories in New Zealand willing to participate in the project.

Continuation of routine data flow on a long term basis from individual Observatories to the Meteorological Service after expiry of the contract was also to be organized (Edwards and Othman, 1976), while data during the contract period were to be collected and analysed at the University of Otago.

At the end of 1977 the contract was formally completed and some of the collected coded "raw" stellar extinction data and their computer evaluations for each observatory in a separate folder, the punch-card program deck, program listing (Borroughs 6700 program) and a sample punched-card data-deck were handed over to the Research Section in 1978.

The computer program was then converted into a form usable by our PDP-11 computer system (F6DA program) and some time was spent with becoming more familiar with the nature and meaning of the astronomical parameters featuring in the stellar data reduction processes.

From the sample card-deck and information on hand at that time it became obvious that the program required the knowledge of more extensive filter and stellar data than was available from the observatory folders and data coding forms (particularly from the earlier version of the form), and while steps in the program were described in detail (Hurst et al., 1977), the derivation of the constants used in the computations and the nature of the final products were not properly understood until a paper by Othman (1981) was published.

In the meantime no further observational data came to hand in spite of circular letters sent to the Observatories asking for their continued cooperation in the project, and offering a small annual honorarium for their participation. A further approach during 1980 did not produce better response, except from the Department of Physics, Canterbury University, where an effort was made to collate some standard star observation data from Mt John Observatory on magnetic tapes. A sample listing of raw stellar data from such a tape was sent to us by Murray Singleton. The format of the data did not appear to be easily convertable into the input format required by the astronomical program, nor was there sufficient information on star and filter characteristics in the listings.

My queries on these points remained unanswered apparently due to the departure of Mr Singleton from Canterbury University (see correspondence on File 33/16/5).

After all these frustrating efforts the astronomical turbidity project finally retreated into oblivion. However, in case the interest in it revives again at some future date, the following chapters summarize the main features of the available observational data, the computational procedures and the final analysis, based on the material collected and described under contract by Prof. Edwards and associates, and later used by Othman (1981).

2. Computation of atmospheric turbidity from stellar extinction data

Two stellar photometric systems are used at the Auckland, Mt John and Beverley Begg (Dunedin) Observatories, namely the Stormgren "intermediate" wavelength-band uvby and the Johnson "wideband" UBV systems. These systems contain filters in the "intermediate" bandwidth range of 9-12 nanometers (nm) and "wide" bandwidths within 20-37 nm.

In addition, the VUW (Victoria University of Wellington) intermediate-band scanning monochromator with 7 nm bandwidth (Trodahl et al., 1973) has been operated at Mt John, and a locally designed stellar photometer with narrowband interference filters in the 3.6-5.7 nm wavelength range was used at the Dunedin Signal Hill Observatory. No data or analysis from the latter has ever been received.

The "mean" wavelengths (in nm) of these systems were given as folows:

u(349), v(411), b(467), y(546)
U(357), B(439), V(556)
VUW(370-720)

Stellar observations useful for turbidity calculations normally are carried out on comparison standard stars, obtained as part of routine astronomical studies of variable stars.

If the intensity of a star as attenuated by unit airmass (at the zenith) is I_λ and the corresponding "extra-terrestrial" intensity is $I_{o\lambda}$, then the extinction coefficient per unit airmass in <u>stellar magnitudes</u> is given as

$$\tau(\lambda) = -2.5 \log_{10} (I_\lambda / I_{o\lambda})$$

The exponential extinction coefficient normally used in solar photometry

$$K(\lambda) = -\ln(I_\lambda / I_{o\lambda})$$

can be obtained then from the expression

$$K(\lambda) = \tau(\lambda)/1.0857 \qquad (1)$$

The optical depth due to haze scattering, or "turbidity" can be calculated by subtraction of the effects of Rayleigh (molecular) scattering and absorption by ozone, water vapor and other gases (NO_2) from the total extinction $\tau(\lambda)$.

For the determination of $\tau(\lambda)$, the astronomical turbidity program requires observatory, stellar and observational data which are entered on the "Atmospheric Extinction Data Coding Form" in a specified format, ready for transfer to punched cards. A sample of such a form with some coded data is found in the Appendix.

The construction of the input data deck to the B6700 computer program (Hurst et al., 1978) is also described in the Appendix, where a listing of the program and analysis of the coded sample data are also included.

It can be noted from the description of the input data deck, that some of the required input parameters are not available from the Data Coding Forms, such as variances of filter passbands (card-type 8), and absolute gradients of stars (card-type 10). (For definition of the astronomical terms consult Allen (1955)).

The "raw" photometric data are first processed by the computer program to yield stellar magnitudes, and relative optical airmasses are calculated for each reading, for each filter (colour), for each star. Then linear regression analysis and Bouguer plots are made of the magnitudes vs airmass for each filter. These plots are analogous to the Langley plots used in solar photometry. The primary purpose of this regression is to edit data by eliminating badly outlying points or even whole sets of observations which give anomalous regressions.

After editing has been done, the program reads the edited data-deck again, and as before, continues with processing into stellar magnitudes and then calculates Rayleigh scattering coefficients in corresponding units at the mean filter wavelengths. The scattering coefficients given by Hoyt (1976) are used in the following expression, valid for the 340-800 mm wavelength range

$$\alpha_R(\lambda) = 0.00905148\ \lambda^{-4} + 0.00011335\ \lambda^{-6}$$

The calculated $\alpha_R(\lambda)$ values have to be corrected for filter bandwidths in the UBV system. The correction procedures involve knowledge of the absolute gradients of the star in the appropriate filter wavelength ranges, gradients being dependent on the spectral energy distribution, or spectral "type" of the star.

Corrections may also be made for the "Forbes" effect, which is a dependence of the bandwidth correction on airmass.

For details of the equations and numerical constants used for calculations of these corrections, see pp. 17-20 of Hurst et. al., (1978) and pp. 122-123 of Othman (1981).

Appendix 1 of Othman (1981) lists "effective" absolute gradients, Rayleigh and ozone optical depths for the U, B, V filters separately for 46 different spectral type stars.

The corrected Rayleigh coefficients are then subtracted from the reduced stellar magnitudes, the resulting values are weighted by the reciprocal of their airmasses, and a new regression and Bouguer plot is made of these weighted values against airmass.

The products from these analyses are listed in the computer output as "extinction coefficients" (the slopes) both in stellar magnitudes and "nepers" per unit airmass, (see expression 1), together with intercept values, and the usual statistical goodness-of-fit estimates.

These "extinction coefficients" require further manipulation to obtain the turbidity or haze optical thickness values, since ozone, water vapor and possibly significant NO_2 absorption effects have not been taken into account by the program.

"Effective" ozone absorption coefficients can be calculated from linear expressions involving again the effective absolute gradients of the star as given by Othman (1981), pp. 129-130, for the U and V filters of the wideband system.

The water-vapor absorption has significance only in the V filter band and it shows little dependence on the spectral type of the star. A constant absorption coefficient has been calculated for all spectral types (see pp. 91, Othman (1981)).

Neither ozone nor water vapor absorption is significant in the B filter wavelength band.

NO_2 absorption is not dependent on spectral type and again, constant coefficients can be used for the U, B, V filters (see pp. 99, Othman (1981)).

With average, or temporal values of total ozone, precipitable water and NO_2 contents, effective optical depths for these parameters can be calculated, using the expressions referred to above, and with their subtraction from the "extinction coefficient" output by the program the final turbidity values can be obtained.

3. Astronomical data available for 1970-77

A summary of the available astronomical data collected under contract at the University of Otago, in the form of raw data or already computed extinction coefficients is given below.

Astronomical Observatory	Period	Obs. System	No. of obs.
Auckland	1970-72	UBV	32
	1973-74		13
	1977		1
Mt John	1973	UBV	6
	1975-77	"	20
	1972, 74, 76	VUW	9
Beverley Begg	1975	UBV	1
	1977	"	2

Some but not all of the above UBV data in coded form and listings of analysis by the B6700 program for most of the UBV data are contained in the Observatory folders, which are filed in Research Section.

Listings of analysed uvby and VUW data are also available in the appropriate folders.

VUW data analysis obtained from D.J. Sullivan and H.J. Trodahl gave aerosol optical depths for 1.0 μm and thus were not directly comparable to the output by the B6700 program.

More complete analysis of all these data was made by Othman (1981). Monthly mean turbidity values normalized to a common wavelength of 0.5 μm were also calculated from the Auckland and Mt. John data.

The resulting time series (see Figs. 7.4 and 7.7 in Othman (1981)) for the period 1970-1974 for Auckland and 1972-1980 for Mt. John did not reveal any significant trends in turbidity.

The calculated period means and standard deviations, presumably in stellar magnitudes for these data were given as 0.122 ± 0.016 for Auckland and 0.06 ± 0.004 for Mt. John.

The solar Volz photometer observations at Lauder for 1980 gave an estimated yearly average value (in stellar magnitudes) of 0.103, and at Auckland of 0.163 at the corresponding wavelength. During 1979 an eight monthly average in corresponding units from observations at Kelburn gave the value of 0.123 (Farkas, 1980). It must be pointed out however, that in all solar photometer data, significant seasonal variations exist which are not evident in the stellar turbidity data as analysed by Othman (1981).

4. Conclusion

Although a great deal of work has been done towards development of a computational program of atmospheric turbidity from stellar extinction observations, and formating of raw data has been worked out for a routine observation network in New Zealand as envisaged by Edwards (1979), the project has not continued past its initial stages.

The computer program at our disposal is not complete and data flow from the Observatories has ceased after 1979.

Final completion of the program would need deeper understanding of the astronomical background and of the nature of the observations provided by the Observatories, both relatively far removed from the normal sphere of knowledge of meteorologists.

It would be preferable that the astronomical observatories themselves evaluate their own stellar extinction observations using a completed routine program, which would give turbidity parameters directly comparable, or at least easily convertable to values comparable with those originating from the solar turbidity monitoring network in New Zealand.

Both methods should comply with standards of observation and evaluation set by the World Meteorological Organization for turbidity measurements and such co-operation between astronomers and meteorologists then would produce internationally acceptable and comparable turbidity parameters on a long term basis.

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APPENDIX A

CARD FORMATS

(a) Observatory Data

Column Nos.	*Information contained*
1,2	01
5-12	*East* longitude in degrees
13-20	Latitude in degrees
21-80	Description or name of observatory in any format desired

(b) Star Data

1,2	02
6-12	Right ascension in format hhm.ss, e.g. 1325.05
13-20	Declination in decimal degrees
21-24	Epoch of star coordinates (not used by program at present; command 04 used instead)
25-46	Name or description of star in any format.
49-50	Star number as in columns 3,4 of photometer (03) cards
52,53	Spectral class
55-58	Luminosity class
60-64	Magnitude
67-70	V
72-75	U-B
77-80	B-V

(c) Photometer Data

1,2	03
3,4	01 thru 99 to identify star, 00 or blank for sky
5-12	Date in format dd/mm/yy (e.g. 06/09/77)
13-20	Time in format hhmm.ss
21-68	Up to 6 photometer readings in fields of 8 columns
69-76	Filter set and sequence of observations corresponding to colour numbers
77-80	Atmospheric pressure in mb

(d) Star Coordinate Precession Command

1,2	04
3-8	No. of years of precession required

(e) Change Program Parameters

1,2	05
5-8	Time option: choice of UTbb, NZST, HAbb
9-12	NOLOG option: choice of 0 or 1
13-16	DELTA: time between different colour readings in *minutes*

(f) X-Y Plot Command

1,2	06
8	Colour no. required to be plotted
9-80	Comments if desired

(g) Linear Regression Command

1,2	07
8	Colour no. required to be analysed
9-80	Comments if desired

(h) Absolute Gradient Data for Star

1,2	10
5-10 17-22 etc . . . 65-70	Fields of 6 columns: Absolute gradient of star spectrum at mean wavelength of each filter for colours 1-6 in order

(i) Filter Data & Rayleigh Substraction Command

1,2	08	
5-10		
11-16		
17-22	Fields of 6 columns:	
etc		
.	Mean wavelength of filter (μm) followed by variance of filter passband (μm^2) for colours 1-6 in order.	
.		
.		
71-76		

If format errors are detected on any card, the card is ignored. With the exception of photometer cards read before star and observatory data has been read, every card which is read successfully will produce some line-printer output (usually self-explanatory).

In all cases, numbers should either be right-justified (i.e. no trailing blanks) in the available card columns, or a decimal point should be punched.

Construction of data deck:
(usual, but not necessary order)

Card types :	01	
	02	
	04	
	05	
	03	(sky background)
	03	(photometer readings), max. 50 cards
	10	
	08	
	06	
	07	
	09	(end of deck : optional)

```
$ PAGE
$ SET LINEINFO SET $
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  %                                                                                %
C  %    A T M O S P H E R I C   S T E L L A R   E X T I N C T I O N                 %
C  %    = = = = = = = = = = = =   = = = = = = =   = = = = = = = = = =               %
C  %                                                                                %
C  %    VERSION #006                                                                %
C  %                                                                                %
C  %    REFERENCE:  RESEARCH REPORT  ASTROPHYS 77/2                                 %
C  %                                                                                %
C  %                             PHYSICS DEPARTMENT,                                %
C  %                             UNIVERSITY OF OTAGO,                               %
C  %                             NEW ZEALAND.                                       %
C  %                                                                                %
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      FUNCTION HRANG(ND,NM,NY,TIM,RA,ELONG)
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  %                                                              %
C  %    SUBROUTINE TO CALCULATE HOUR ANGLE.                       %
C  %                                                              %
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      I = NY-76
      J = NM-3
      IF(J) 30,35,35
   30 J = J+12
      I = I-1
   35 K = (5+6*J)/10
      K = K + ND - 1 + I*365 + 30*J + I/4
      IF(I .LT. 0) K = K-1
      TD = FLOAT(K) + TIM/24.
      R = TD/365.24219
      R = (R-AINT(R))*24. + 10.59500
      TH =TIM + R - RA*3.81972 + ELONG/15. + 96.0
      TH = TH - 24.*AINT(TH/24.)
      IF(TH-12.) 45,45,40
   40 TH = TH-24.
   45 HRANG = TH
      RETURN
      END
      FUNCTION AMASS(F)
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  %                                                              %
C  %    SUBROUTINE TO CALCULATE THE RELATIVE AIRMASS.             %
C  %                                                              %
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      IF (F-0.0672) 11,11,12
   11 AMASS = 25.944*EXP(-21.7*F)+6.234
      RETURN
   12 SEC = 1./F
      T=SEC*SEC-1.
      T=1.-T*(0.00118-2.15E-6*T)
      AMASS=SEC*T

      RETURN
      END
      SUBROUTINE LISTER(J)
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  %                                                              %
C  %    SUBROUTINE TO LIST J ROWS OF ARRAYS AX, AY.               %
C  %                                                              %
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      DIMENSION OBNAME(10),STNAME(10),AX(50,6),AY(50,6)
      COMMON OBNAME,STNAME,AX,AY
      WRITE(6,300)  OBNAME,STNAME
  300 FORMAT(' ',10A6/' ',10A6/' PT.NO. ',6('MAGNITUDE  AIRMASS  '))
      DO 380 I = 1,J
      WRITE(6,320)I,AY(I,1),AX(I,1),AY(I,2),AX(I,2),AY(I,3),AX(I,3),
     1 AY(I,4),AX(I,4),AY(I,5),AX(I,5),AY(I,6),AX(I,6)
  320 FORMAT(' ',I4,6(F12.4,F8.4))
  380 CONTINUE
      RETURN
      END
      SUBROUTINE PREC(RA,DEC,YEARS)
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C  %                                                              %
C  %    SUBROUTINE TO PRECESS THE STELLAR COORDINATES.            %
C  %                                                              %
C  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      DEC = DEC + YEARS*9.72E-5*COS(RA)
      RINC = 2.235E-4 + 9.72E-5*SIN(RA)*TAN(DEC)
      RA = RA + YEARS*RINC
      RINC = DEC*57.29578
      TH = RA*3.81972
      TM = (TH-AINT(TH))*60.
      TS = (TM-AINT(TM))*60.
      WRITE(6,1) YEARS,AINT(TH),AINT(TM),TS,RINC
    1 FORMAT('0PRECESSED BY',F5.1,' YEARS,RA=',F5.0,'HR',F5.0,
     1  'MIN',F5.0,'SEC ,  DEC=',F8.2,'  DEGREES')
      RETURN
      END
```

```
      SUBROUTINE POLYI(J,K)
C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C   %                                                           %
C   %     SUBROUTINE TO PERFORM A WEIGHTED LINEAR REGRESSION    %
C   %     ANALYSIS ON THE FIRST K VALUES OF THE JTH COLUMNS     %
C   %     OF THE ARRAYS AX, AY.                                 %
C   %                                                           %
C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      DIMENSION OBNAME(10),STNAME(10),AX(50,6),AY(50,6)
      COMMON OBNAME,STNAME,AX,AY
      WRITE(6,10)
   10 FORMAT('0DATA FOR     LINEAR REGRESSION:'
     1      /'0PT. NO.      X VALUE     Y VALUE     WEIGHT ASSIGNED')
      DO 30 I = 1,K
      X = AX(I,J)
      Y = AY(I,J)
      IF((Y.LE.-100.).OR.(X.GE.40.).OR.(X.LE.0.))   GO TO 20
      W = 1./X
      WRITE(6,15) I,X,Y,W
   15 FORMAT(' ',I4,3X,3F10.4)
      N = N+1
      WSUM = WSUM + W
      XSUM = XSUM + X*W
      YSUM = YSUM + Y*W
      X2SUM = X2SUM + X*X*W
      Y2SUM = Y2SUM + Y*Y*W
      XYSUM = XYSUM + X*Y*W
      GO TO 30

   20 WRITE(6,25) I,X,Y
   25 FORMAT(' ',I4,3X,2F10.4,'     INVALID DATUM; OMITTED FROM ANALYSIS')
   30 CONTINUE
      IF (WSUM .EQ. 0.0) GO TO 50
      XMEAN = XSUM/WSUM
      YMEAN = YSUM/WSUM
      X2AV = X2SUM/WSUM
      XVAR = X2AV - XMEAN*XMEAN
      XYAV = XYSUM/WSUM
      IF( N .LE. 1) GO TO 35
      SLOPE = (XYAV - XMEAN*YMEAN)/XVAR
      YCEPT = YMEAN - XMEAN*SLOPE
      Y2AV = Y2SUM/WSUM
      S2YONX = Y2AV - YCEPT*YMEAN - SLOPE*XYAV
      R = SQRT(1. - S2YONX/(Y2AV-YMEAN*YMEAN))
      DF = FLOAT(N-2)
      IF (DF .EQ. 0.0) GO TO 35
      ERSL = SQRT(S2YONX/(DF*XVAR))
      ERYC = ERSL*SQRT(X2AV)
      ERREST = SQRT(S2YONX)
   35 WRITE(6,40) SLOPE,ERSL,SLOPE/1.0857,ERSL/1.0857
 40   FORMAT('0EXTINCTION COEFF:'/'0STELLAR MAGNITUDES PER AIRMASS:',
     1  F7.4,' +OR-',F7.4
     1 /'                    NEPERS PER AIRMASS:',F7.4,' +OR-',F7.4)
      WRITE(6,45)YCEPT,ERYC
   45 FORMAT('0ZERO AIRMASS INTERCEPT=',F9.4,' +OR-', F9.4)
      WRITE(6,60) N,ERREST,R
   60 FORMAT('0N=',I4/'0NORMALIZED STD ERR OF ESTIMATE=', F7.5
     1  /'0CORRELATION COEFF=', F7.5)
      WRITE(6,65) XMEAN,YMEAN,X2AV,Y2AV,XYAV
   65 FORMAT('0QUANTITY:',10X,'X',10X,'Y',9X,'X**2',8X,'Y**2',8X,
     1   'XY'/   ' WEIGHTED AV:',F11.7,F12.7, F11.7,2F12.7)
      RETURN
   50 WRITE(6,55)
   55 FORMAT('0PLEASE CHECK HOUR ANGLES,AIRMASSES AND MAGNITUDES')
      RETURN
      END
```

```
      SUBROUTINE PLOT(J,K)
C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C   %                                                                    %
C   %     SUBROUTINE TO PRODUCE AN X-Y PLOT OF THE FIRST K               %
C   %     VALUES OF THE JTH COLUMNS OF THE ARRAYS AX, AY.                %
C   %                                                                    %
C   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      DIMENSION XX(50),YY(50),AX(50,6),AY(50,6),
     1  OBNAME(10),STNAME(10)
      COMMON OBNAME,STNAME,AX,AY
      YMIN = 200
      YMAX = -98.
      DO 30 I = 1,K
      P = AX(I,J)
      Q = -AY(I,J)
      IF(P .GE. 40.) Q=100.
      IF(Q .GT. 99.) GO TO 20
      YMAX = AMAX1(Q,YMAX)
      YMIN = AMIN1(Q,YMIN)
      XMAX = AMAX1(P,XMAX)
      GO TO 25
   20 Q = -Q
   25 XX(I) = P
      YY(I) = Q
   30 CONTINUE
      P = 0.016
      XMAX=AMAX1(XMAX,P)
   32 P = P*10.
      IF(P.LT.XMAX) GO TO 32
   33 P = P/2.
      IF (P.GE.XMAX) GO TO 33
      XMAX = P+P
      XSCALE = 80./XMAX
      YRANGE = YMAX - YMIN
      Q = 0.012
      YRANGE=AMAX1(YRANGE,Q)
   37 Q = Q*10.
      IF (Q.LT.YRANGE) GO TO 37
   38 Q = Q/2.
      IF (Q.GE.YRANGE) GO TO 38
      WRITE(6,120)
      YDIV = Q/3.0
      YMIN = YDIV*AINT((YMIN+100.)/YDIV) - 100.
      YRANGE = (YMAX - YMIN)/YDIV
      IF(YRANGE .LE. 5.0) YMIN = YMIN-YDIV
      YSTEP = YDIV/8.
      Q = YSTEP/2.
      YMAX = YMIN + 7.*YDIV - Q
      L = 1
      GO TO 42
   40 WRITE(6,41)
   41 FORMAT(' ',T11,'|',T91,'|')
      YMAX = YMAX-YSTEP
   42 IF (MOD(L, 8).EQ.1) WRITE(6,45) (-YMAX-Q)
 45   FORMAT('+',F9.3,T11,'-',T91,'-')
      IF(L-K) 46,46,48
   46 WRITE(6,47) L,AY(L,J),XX(L)
   47 FORMAT('+',T100,I2,2F12.4)
   48 DO 70 I = 1,K
      IF (YMAX - YY(I)) 60,60,70
   60 N = INT(XX(I)*XSCALE + 10.5)
      YY(I) = -100000.
      WRITE(6,71) N,I
   71 FORMAT('+',T*,I2)
   70 CONTINUE
      L = L+1
      IF (YMAX-YMIN) 90,40,40
   90 WRITE(6,120)
  120 FORMAT('+',9X,9('---------')/'+',9('         |')  )
      Q = P/2.
      WRITE(6,140) Q,P,P+Q,XMAX
  140 FORMAT(' ',T9,'0.00' ,T26,F8.2,T46,F8.2,T66,F8.2,T86,F8.2)
      RETURN
      END
```

```
      %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C     %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C     %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C     %                                                           %
C     %                  M A I N     P R O G R A M                %
C     %                  = = = =     = = = = = = =                %
C     %                                                           %
C     %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
C     %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      DIMENSION OBNAME(10),STNAME(10),C(24),S(6),AX(50,6),AY(50,6),
     1  STASH(13),PR(50),F(12),TLINE(12),PHI(6)
C    ARAAYS C AND CTEST ARE DIMENSIONED LARGER THAN 6 TO GET AROUND A
C     BUG IN THE FORTRAN COMPILER.
      DOUBLE PRECISION CTEST(12),BLANKS,AFLAG
      DATA BLANKS,AFLAG/'        ','-100.00'/
      COMMON OBNAME,STNAME,AX,AY
      DATA TOPT,NOLOG,DELTA,JUMP,PRES1/'UT      ',0,0.25,1,1013.25/
C
C  (03)  READ CONTENTS OF STASH AS PHOTOMETER READINGS.
C

    3 IF((ICOUNT.GE.50.).OR.(READY.EQ.0.).OR.(STEADY.EQ.0.))GO TO 999
      IF (JUMP .EQ. 0) WRITE(6,45)
   45 FORMAT( T73,'COLOUR 1  COLOUR 2  COLOUR 3  COLOUR 4  ',
     1  'COLOUR 5  COLOUR 6')
      JUMP = 1
      READ(STASH,60,DATA=9999)TESTNS,ND,NM,NY,TIM,(CTEST(I),I=1,6),
     1 FSEQ1,FSEQ2,PRES
   60 FORMAT(A2,I2,1X,I2,1X,I2,F8.0,6A8,A6,A2,F4.0)
      DO 5030 I=1,6
      IF(CTEST(I) .IS. BLANKS) CTEST(I)=AFLAG
 5030 CONTINUE
      READ(CTEST,5040,DATA=9999)(C(I),I=1,6)
C     N.B. C ELEMENTS ARE EXPLICITLY REFERENCED ABOVE BECAUSE C HAS TO
C     BE DIMENSIONED LARGER THAN 6 BECAUSE OF A COMPILER BUG.
 5040 FORMAT(6(F8.0,4X))
      IF(TESTNS .IS. '  ') GO TO 5200
      READ(STASH,5020,DATA=9999)NSTAR
 5020 FORMAT(I2)

 5200 IF(NY .LE. 0) GO TO 80
   70 ND1=ND
      NM1=NM
      NY1=NY
   80 IF (PRES .GT. 650.) PRES1 = PRES
      IF(NSTAR .GT. 0) GO TO 110
      DO 105 J = 1,6
      S(J) = C(J)
  105 CONTINUE
      WRITE(6,108)ND1,NM1,NY1,TIM,TOPT,(C(I),I=1,6)
  108 FORMAT(/' SKY READING',6X,'DATE:',3I3,'   TIME:',F8.0,1X,A4,18X,
     1  6F10.2)
      GO TO 999
  110 ICOUNT = ICOUNT + 1
      WRITE(6,112)NSTAR,ICOUNT,ND1,NM1,NY1,TIM,TOPT,
     1    (C(I),I=1,6)
C     N.B. C ELEMENTS ARE EXPLICITLY PRINTED ABOVE BECAUSE C HAS TO
C     BE DIMENSIONED LARGER THAN 6 BECAUSE OF A COMPILER BUG.
  112 FORMAT(/' STAR',I2,' PT.NO.',I2,'  DATE:',3I3,'   TIME:',
     1 F8.0,1X,A4,9X,'RAW DATA:',6F10.2)
      PR(ICOUNT) = PRES1
      K = 6
      DO 120 I=1,6
      P = C(I)
      IF (NOLOG.EQ.1) GO TO 118
      P = P-S(I)
      IF (P.GT.0.0) GO TO 117
      C(I) = -100
      GO TO 118
  117 C(I) = (-1.0857)*ALOG(P)
      K = 1
  118 AY(ICOUNT,I) = C(I)
  120 CONTINUE
      TH=AINT(TIM/100.)
      TM=AINT(TIM-100.*TH)
      TS=100.*(TIM-AINT(TIM))
      TIM=TH+TM/60.+TS/3600.
      IF(TOPT.EQ. 'NZST  ')  TIM =  TIM-12.
      IF (TOPT.NE. 'HA    ') TIM = HRANG(ND1,NM1,NY1,TIM,RA,ELONG)
      T = TIM*0.2618
      ATIM = ABS(TIM)
      TH = AINT(ATIM)
      TM = (ATIM - TH)*60.
      TS = (TM - AINT(TM))*60.
      TM = AINT(TM)
      IF (ATIM .NE. TIM) TH = -TH - 0.1
```

```
      WRITE(6,171) TH,TM,TS,(C(I),I=1,K)
  171 FORMAT(' HR.ANGLE 1ST READING:',F5.0,'HR',F4.0,'MIN',F4.0,'SEC',
     1        9X,'STELLAR MAGNITUDE:',6F10.4)
      P=SIN(ELAT)*SIN(DEC)
      Q=COS(ELAT)*COS(DEC)
      DO 170 I=1,K
      C(I)=P+Q*COS(T)
      T = T + 0.004363*DELTA
  170 CONTINUE
      WRITE(6,175) PRES1,(C(I),I=1,K)
  175 FORMAT(' PRESSURE:',F7.1,T46,'COSINES OF ZENITH ANGLES:', 6F10.4)
      DO 180 I = 1,K
      IF(C(I)) 177,178,178
  177 C(I) = 40.
      GO TO 179
  178 C(I) = AMASS(C(I))
  179 AX(ICOUNT,I) = C(I)
  180 CONTINUE
      WRITE(6,185) FSEQ1,FSEQ2,(C(I),I=1,K)
  185 FORMAT(' FILTER INFO:   ', 2A6,T61,'AIRMASSES:', 6F10.4)
  999 READ(5,1000,DATA=9999,END=9)NCOMND,STASH
 1000 FORMAT(I2,13A6)
C
C    (99)  COMMENT COMMAND.  ECHOED ON THE LINEPRINTER.
C
      IF(NCOMND .EQ.99) WRITE(6,5800) STASH
 5800 FORMAT('0','COMMENT CARD: ',13A6)
      GO TO (1,2,3,4,5,6,7,8,9,10) NCOMND
      GO TO 999
C
C    (01)  READ CONTENTS OF STASH AS DATA DESCRIBING AN OBSERVATORY.
C
    1 READ(STASH,19,DATA=9999) ELONG,ELAT,OBNAME
   19 FORMAT(2X,2F8.0,10A6)
      READY = 1.
      WRITE(6,20) JUMP,OBNAME,ELONG,ELAT
   20 FORMAT(I1,'OBSERVATORY:',10A6/' LONGITUDE=',F8.2,3X,
     1 'LATITUDE=',F8.2)
      ELAT=ELAT/57.29578
      ICOUNT = 0
      JUMP = 0
      GO TO 999
C
C    (02)  READ CONTENTS OF STASH AS DATA DESCRIBING A STAR.
C
    2 READ(STASH,15,DATA=9999) NSTAR,RA,DEC,STNAME
   15 FORMAT(I2,2F8.0,10A6)
      STEADY = 1.
      TH=AINT(RA/100.)
      TM=AINT(RA-100.*TH)
      TS=100.*(RA-AINT(RA))
      WRITE(6,40) JUMP,STNAME,TH,TM,TS,DEC
   40 FORMAT(I1,'STAR:',10A6/' RA=',F5.0,'HR',F5.0,'MIN',F5.0,'SEC',
     1   5X,'DEC=',F8.2,'  DEGREES')
      RA=TH+TM/60.0+TS/3600.0
      RA=0.2617994*RA
      DEC=DEC/57.29578
      ICOUNT=0
      JUMP = 0
      TESTNS='  '
      ND=0
      NM=0
      NY=0
      DO 6767 I=1,6
      CTEST(I)=0


 6767 PHI(I)=0
      PRES=0
      GO TO 999
C
C    (04)  PRECESS THE STELLAR COORDINATES.
C
    4 READ(STASH,206,DATA=9999) YRS
  206 FORMAT(F6.0)
      CALL PREC(RA,DEC,YRS)
      GO TO 999
C
C    (05)  UPDATE THE PROGRAM PARAMETERS TOPT,NOLOG,DELTA
C
    5 READ(STASH,200,DATA=9999) TOPT,NOLOG,DELTA
  200 FORMAT(2X,A4,I4,F4.0)
      WRITE(6,501) TOPT,NOLOG,DELTA
  501 FORMAT('0','UPDATED PARAMETERS: TIME OPTION (TOPT)=',A4,
     1                       ' ; PHOTOMETER DATA SCALE (NOLOG)=',F8.3,
     1                       ' ; TIME BETWEEN READINGS (DELTA)=',F8.3)
      GO TO 999
```

```
C
C   (06)  PRINT AN X-Y PLOT OF THE ACCUMULATED DATA FOR A SPECIFIED
C         COLOUR.
C
    6  READ(STASH,205,DATA=9999) J,TLINE
  205  FORMAT(5X,I1,12A6)
       WRITE(6,601)OBNAME,STNAME,J,ND1,NM1,NY1,TLINE
  601  FORMAT('1',10A6/' ',10A6/' COLOUR NO.',I3,T97,'PT.NO.',3X,
      1 'STAR MAG. ',4X,'AIRMASS',/' DATE:',3I3//10X,12A6//)
       CALL PLOT(J,ICOUNT)
       GO TO 999
C
C   (07)  PERFORM A LINEAR REGRESSION ANALYSIS OF STELLAR MAGNITUDE VS.
C         AIRMASS FOR A SPECIFIED COLOUR.
C
    7  READ(STASH,205,DATA=9999) J,TLINE
       WRITE(6,6910)
 6910  FORMAT(' ----------------------------------------------------------
      1-------------------------------------------------------------------')
       WRITE(6,701)OBNAME,STNAME,J,ND1,NM1,NY1,TLINE
  701  FORMAT(/' ',10A6/' ',10A6/'OCOLOUR NO.',I3/' DATE:',3I3/10X,12A6
      1 //)
       CALL POLY1(J,ICOUNT)
       GO TO 999
C
C   (08)  READ THE CONTENTS OF STASH AS DATA DESCRIBING THE FILTERS
C         USED IN THE OBSERVATIONS. SUBTRACT THE CALCULATED RAYLEIGH
C         EXTINCTION FROM EACH STORED STELLAR MAGNITUDE.
C
    8  READ(STASH,210,DATA=9999) F
  210  FORMAT(2X,12F6.0)
       WRITE(6,801)
  801  FORMAT(//' FILTER DATA'/'OCOLOUR NO.  LAMDAO    SIGMA**2')
       DO 260 J = 1,6
       WAVL = F(J+J-1)
       VAR = F(J+J)
       WRITE(6,802) J,WAVL,VAR
  802  FORMAT(' ',I6,2F10.4)
       IF (WAVL .LT. 0.2) GO TO 260
       W2 = WAVL*WAVL
       W4 = W2*W2
       A1 = 0.0090515/W4
       A2 = 0.0001133E/(W4*W2)
C*****THE ABOVE 2 LINES CORRECT THE RAYLEIGH SUBTRACTION.
C*****PREVIOUSLY: A1 = 0.00926/W4, A2 = 0.0001234/(W4*W2)
C*****DATE OF CHANGE 31/10/77  AJR
       RAYK = A1 + A2
       DERIV1 = (-4. * A1 - 6. * A2)/WAVL
       DERIV2 = (20. * A1 + 42. * A2)/W2
       DO 250 I=1,ICOUNT

       X = AX(I,J) *(PR(I)/1013.25)
       P = -DERIV2*X*VAR/2.
       Q =(DERIV1**2) * (X**2) * VAR/(2.*1.0857)
       STRFAC = -X * DERIV1 * ((PHI(J)/W2) - (5/WAVL)) * VAR
C*****STRFAC CORRECTS THE OBSERVED INTENSITY FOR STAR COLOUR
C*****PHI(J) IS THE ABSOLUTE GRADIENT OF STAR INTENSITY(LAMBDA).
C*****PHI(J) IS LOOKED UP AS A FUNCTION OF STAR SPECTRAL CLASS.
       EXT = X*RAYK
       AY(I,J) = AY(I,J) + P + Q - EXT + STRFAC
       PRINT /,AY(I,J),P,Q,EXT,STRFAC,X,RAYK
  250  CONTINUE
  260  CONTINUE
       WRITE(6,270)
  270  FORMAT('ODATA AFTER SUBTRACTION OF RAYLEIGH EXTINCTION')
       CALL LISTER(ICOUNT)
       GO TO 999
C
C   (09)  STOP COMMAND.
C
    9  STOP

 9999  WRITE(6,7030)NCOMND,STASH
 7030  FORMAT(' >>>>>DATA ERROR IN THIS CARD:',I2,13A6)
       GOTO 999
C
C   (10)  ENTER PHI(J) VALUES FOR STAR.
C
   10  READ (STASH,7577,DATA=9999)PHI
 7577  FORMAT(2X,6(F6.0,6X))
       WRITE(6,7578)PHI
 7578  FORMAT('1',/,6(' PHI=',F10.4'      '))
       GOTO 999
       END
```

rev. 30/11/77

ATMOSPHERIC EXTINCTION DATA CODING FORM

PAGE .... OF ....

TIME INFO: NZST ○ UT ○ HA ○ (tick one)

PHOTOMETER DATA: Direct Observations ○ Instr. Magnitudes ○ (tick one)

Time Interval Between Successive Colour Readings: ________
(if this varies by more than ±10 s, use one colour per 03 row and specify the time for each reading)

Observer: ________ Recorder: ________
Moon: present absent rising setting phase ________
Seeing: v. steady steady unsteady turbulent
Transparency: Excellent good fair poor
Horizontal visibility: ________ km
Obstruction to vision: Haze Smoke Fog
Temperature: ________ °C Dew Point: ________ °C
Wind Speed: ________ m s^{-1} Direction: ________
Sky Cover: ________ eighths Humidity: ________ %

	EAST LONGITUDE (decimal degrees)	LATITUDE (decimal degrees)	NAME OF OBSERVATORY AND DETAILS OF INSTRUMENTATION	ALTITUDE (m)
01				
1	5	13	21–74	76–80

	R.A. HHMM.SS	DEC. (decimal degrees)	EPOCH	NAME OF STAR	STAR NO.	SPECTRAL CLASS	LUMINOSITY CLASS	MAGNITUDE	V	U - B	B - V
02	.										
02	.										
02	.										
02	.										
1	6	13	21	25–46	49 50	52 53	55 58	60 64	67 70	72 75	77 80

	STAR No.	DATE DAY/MONTH/YEAR	TIME HHMM.SS	COLOUR 1	COLOUR 2	COLOUR 3	COLOUR 4	COLOUR 5	COLOUR 6	COLOUR SEQUENCE	ATM. PRES. (mb)
03		/ /	.								
03		/ /	.								
03		/ /	.								
03		/ /	.								
03		/ /	.								
03		/ /	.								
03		/ /	.								
03		/ /	.								
03		/ /	.								
03		/ /	.								
1	3	5 8 11	14	21	29	37	45	53	61	69	77 80

NOTES: Please use a sharp 2B pencil to fill in this form. Coding Conventions: ALPHA: θ,I,Ƶ; NUMERIC: 0 (zero), 1 (one), 2 (two)

In general, numbers must be right-justified within their field unless they contain a decimal point.
The Star-Number is 00 for SKY, 01, 02, 03,....99 for each successive star in one data batch.

RBA 43/77

SUPPLEMENTARY ATMOSPHERIC EXTINCTION DATA CODING FORM

CONTINUATION INFORMATION: ______________________________

	STAR No.	DATE DAY	DATE MONTH	DATE YEAR	TIME H H M M . S S	COLOUR 1	COLOUR 2	COLOUR 3	COLOUR 4	COLOUR 5	COLOUR 6	COLOUR SEQUENCE	ATM. PRES. (mb)
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
0 3		/	/		.								
1	3	5	8	11	14	21	29	37	45	53	61	69	77 80

NOTES: Please use a sharp 2B pencil to fill in this form. Coding Conventions: ALPHA: θ. I, Z; NUMBERIC: 0 (zero), I (one), 2 (two)

In general, numbers must be right-justified within their field unless they contain a decimal point.
The Star-Number is 00 for SKY, 01, 02, 03, ... 99 for each successive star in one data batch.

RBA 41/77

rev. 5/9/77

BBO #4

ATMOSPHERIC EXTINCTION DATA CODING FORM

TIME INFO: NZST ○ UT ✓ HA ○ (tick one)

PHOTOMETER DATA: Direct Observations ✓ Instr. Magnitudes ○ (tick one)

Time Interval Between Successive Colour Readings: 40s
(if this varies by more than ±10 s, use one colour per 03 row and specify the time for each reading)

Observer: MT Recorder: WHA
Moon: present absent rising setting phase 8 days
Seeing: v. steady (steady-unsteady) turbulent
Transparency: Excellent (good) fair poor
Horizontal visibility: ______ km
Obstruction to vision: Haze Smoke Fog
Temperature: ______ °C Dew Point: ______ °C
Wind Speed: 0 m s^{-1} Direction: —
Sky Cover: 0 eighths Humidity: ______ %

	EAST LONGITUDE (decimal degrees)	LATITUDE (decimal degrees)	NAME OF OBSERVATORY AND DETAILS OF INSTRUMENTATION	ALTITUDE (m)
01	170.5	-45.87	BBO. 60" APERTURE. TUBE 1. 1120V.	140

	R.A. HHMM.SS	DEC. (decimal degrees)	EPOCH	NAME OF STAR	SPECTRAL CLASS	MAGNITUDE	U	B	V	U-B	B-V
02	1626.20	-26.323		ALPHA-SCORPII (~~?~~ +84)							

	STAR No.	DAY	MONTH	YEAR	TIME HHMM.SS	COLOUR 1	COLOUR 2	COLOUR 3	COLOUR 4	COLOUR 5	COLOUR 6	COLOUR SEQUENCE	ATM. PRES. (mb)
03	01	21	09	77	0907.	260683	123807	7551				VBU	
03	01	/	/		0927.	249015	115877	6794					
03	01	/	/		0949.	241128	109540	6047					
03	01	/	/		1002.	231866	103213	5510					
03	01	/	/		1044.	198724	82754	3535					
03	00	21	09	77	0910.	309	780	123					
03	00	21	09	77	0920.	286	475	132					
03	00	21	09	77	0939.	306	504	138					
03	00	21	09	77	0952.	378	549	136					
03	00	21	09	77	1014.	376	606	157					

Only these sky readings for whole data set. +2 on next sheet.

NOTES: Please use a sharp pencil to fill in this form. Coding Conventions: ALPHA: θ, I, Z; NUMERIC: 0 (zero), 1 (one), 2 (two)
In general, numbers must be right-justified within their field unless they contain a decimal point.
The Star-Number is 00 for SKY, 01, 02, 03,....99 for each successive star in one data batch.

```
OBSERVATORY:8804. 60" APERTURE. TUBE 1.   1120V.
LONGITUDE=  170.50   LATITUDE=  -45.87

STAR:1950ALPHA-SCORPII              01 M2  I           0.89 1.83 1.34
RA=  16.HR  26.MIN  20.SEC       DEC=  -26.32  DEGREES

PRECESSED BY 27.8 YEARS,RA=  16.HR  28.MIN   2.SEC ,  DEC=  -26.38  DEGREES
                                                              COLOUR 1   COLOUR 2   COLOUR 3   COLOUR 4   COLOUR 5   COLOUR 6

STAR 1 PT.NO. 1  DATE: 21  9 77  TIME:     907. UT          RAW DATA: 260683.00 123807.00    7551.00    -100.00    -100.00    -100.00
HR.ANGLE 1ST READING:   4.HR  1.MIN 29.SEC        STELLAR MAGNITUDE:  -13.5398   -12.7314    -9.6947
PRESSURE: 1022.0                              COSINES OF ZENITH ANGLES:    0.6273     0.6267     0.6261
FILTER INFO: VBU                                          AIRMASSES:    1.5912     1.5927     1.5942

SKY READING       DATE: 21  9 77  TIME:     910. UT                        309.00     780.00     123.00    -100.00    -100.00    -100.00

STAR 1 PT.NO. 2  DATE: 21  9 77  TIME:     927. UT          RAW DATA: 249015.00 115877.00    6794.00    -100.00    -100.00    -100.00
HR.ANGLE 1ST READING:   4.HR 21.MIN 33.SEC        STELLAR MAGNITUDE:  -13.4888   -12.6522    -9.5602
PRESSURE: 1022.0                              COSINES OF ZENITH ANGLES:    0.5788     0.5781     0.5775
FILTER INFO:                                              AIRMASSES:    1.7238     1.7256     1.7275

SKY READING       DATE: 21  9 77  TIME:     920. UT                        286.00     475.00     132.00    -100.00    -100.00    -100.00

SKY READING       DATE: 21  9 77  TIME:     939. UT                        306.00     504.00     138.00    -100.00    -100.00    -100.00

STAR 1 PT.NO. 3  DATE: 21  9 77  TIME:     949. UT          RAW DATA: 241128.00 109540.00    6047.00    -100.00    -100.00    -100.00
HR.ANGLE 1ST READING:   4.HR 43.MIN 36.SEC        STELLAR MAGNITUDE:  -13.4538   -12.5935    -9.4285
PRESSURE: 1022.0                              COSINES OF ZENITH ANGLES:    0.5231     0.5224     0.5218
FILTER INFO:                                              AIRMASSES:    1.9059     1.9082     1.9105

SKY READING       DATE: 21  9 77  TIME:     952. UT                        378.00     549.00     130.00    -100.00    -100.00    -100.00

STAR 1 PT.NO. 4  DATE: 21  9 77  TIME:    1002. UT          RAW DATA: 231866.00 103213.00    5510.00    -100.00    -100.00    -100.00
HR.ANGLE 1ST READING:   4.HR 56.MIN 39.SEC        STELLAR MAGNITUDE:  -13.4109   -12.5281    -9.3254
PRESSURE: 1022.0                              COSINES OF ZENITH ANGLES:    0.4892     0.4886     0.4879
FILTER INFO:                                              AIRMASSES:    2.0365     2.0392     2.0419

SKY READING       DATE: 21  9 77  TIME:    1014. UT                        376.00     606.00     157.00    -100.00    -100.00    -100.00

SKY READING       DATE: 21  9 77  TIME:    1029. UT                        438.00     644.00     150.00    -100.00    -100.00    -100.00

STAR 1 PT.NO. 5  DATE: 21  9 77  TIME:    1044. UT          RAW DATA: 198724.00  82754.00    3535.00    -100.00    -100.00    -100.00
HR.ANGLE 1ST READING:   5.HR 38.MIN 45.SEC        STELLAR MAGNITUDE:  -13.2428   -12.2856    -8.8236
PRESSURE: 1022.0                              COSINES OF ZENITH ANGLES:    0.3767     0.3760     0.3753
FILTER INFO:                                              AIRMASSES:    2.6359     2.6406     2.6453

COMMENT CARD: THE RAYLEIGH SUBTRACTION CARDS GO HERE AFTER EDITING HAS BEEN COMPLETED.

COMMENT CARD: THE FOLLOWING CARDS ARE FOR THE RAYLEIGH SUBTRACTION.
```

```
PHI=   4.1500    PHI=   8.9000    PHI=   6.0500    PHI=   0.0000    PHI=   0.0000    PHI=   0.0000

FILTER DATA
             wavelength   variance
COLOUR NO.   LAMDA0       SIGMA**2
 (1)         0.5500       0.0014
 -13.70422753294985          -7.9660152867220258E-03
 9.6952384129080267E-04       0.1653257412140583
 7.9454014422855596E-03       1.604922615453070
 0.1030116590184548
 -13.66677767011461          -8.6516312910968036E-03
 1.1378741314389371E-03       0.1791052614549179
 8.6076323761482577E-03       1.738689223739525
 0.1030116590184548
 -13.65047357192799          -9.5654807334026230E-03
 1.3909509690207976E-03       0.1980236871006165
 9.5168343268383435E-03       1.922342470624029
 0.1030116590184548
 -13.62092901354266          -1.0220830605886497E-02
 1.5880735044574019E-03       0.2115906788396728
 1.0168851338462713E-02       2.054045928934760
 0.1030116590184548
 -13.51406894081671          -1.3229375479380232E-02
 2.6605835683312368E-03       0.2738732933011170
 1.3162095893952379E-02       2.658663066984018
 0.1030116590184548
 (2)         0.4450       0.0013
 -12.98538274653147          -2.7575203845398049E-02
 7.9726475798700181E-03       0.3942507832512746
 0.1599094507379210           1.606428502205315
 0.2454206848982352
 -12.92666107218635          -2.9877244913109707E-02
 9.3593609889858834E-03       0.4271637400914245
 0.1732590573184484           1.740536826667849
 0.2454206848982352
 -12.89586713334382          -3.3038304551850393E-02
 1.1444599741686269E-02       0.4723583375807007
 0.1915901388732704           1.924688368368649
 0.2454206848982352
 -12.85040045343657          -3.5305576667666333E-02
 1.3069281966334313E-02       0.5047741953696738
 0.2047381203978359           2.056771195056279
 0.2454206848982352
 -12.69790962968653          -4.5718246736859870E-02
 2.1915139438153358E-02       0.6536471928163129
 0.2651215115355200           2.663374495460114
 0.2454206848982352
 (3)         0.3630       0.0004
 -10.48691455250677          -3.0523735402429548E-02
 2.0516676647907274E-02       0.9178923435788309
 0.1356730508324092           1.607938143669288
 0.5708505312799011
 -10.41676988738805          -3.3076041676625160E-02
 2.4091215608185323E-02       0.9946438406241726
 0.1470176380630813           1.742389270259742
 0.5708505312799011
 -10.37303851981134          -3.6581311011824080E-02
 2.9467967693504766E-02       1.100052298748359
 0.1625979914643192           1.927040860033777
 0.5708505312799011
 -10.33276530484427          -3.9095888710895085E-02
 3.3658428341567420E-02       1.175669243623560
 0.1737748813007102           2.059504509854126
 0.5708505312799011
 -10.1157287373606          -5.0649006562050059E-02
```

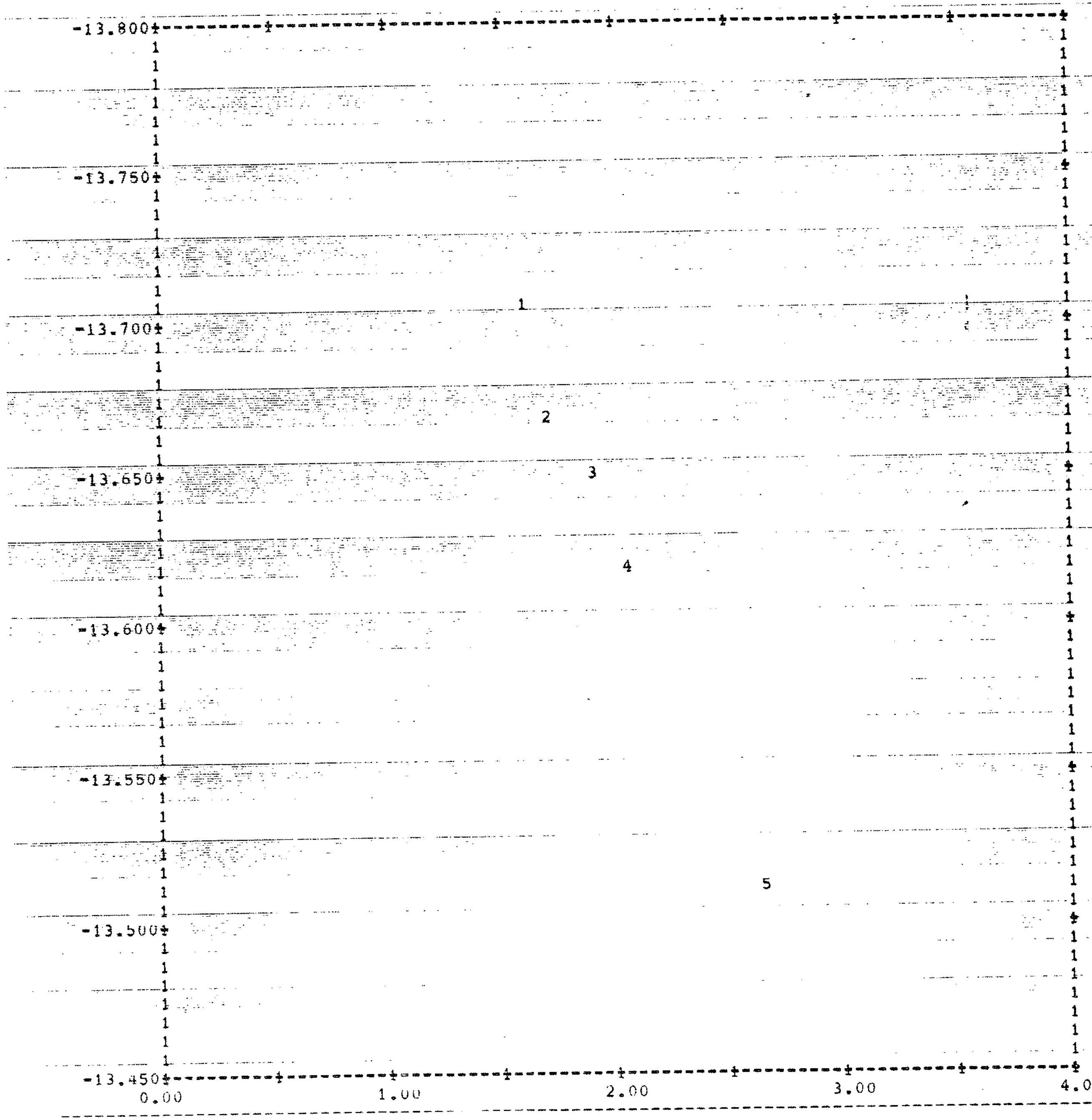
4	0.0000	0.0000
5	0.0000	0.0000
6	0.0000	0.0000

DATA AFTER SUBTRACTION OF RAYLEIGH EXTINCTION
BB04. 60" APERTURE. TUBE 1. 1120V. 141
1950ALPHA-SCORPII 01 M2 I 0.89 1.83 1.34

PT.NO.	MAGNITUDE	AIRMASS	MAGNITUDE	AIRMASS	MAGNITUDE	AIRMASS	MAGNITUDE	AIRMASS	MAGNITUDE	AIRMASS	MAGNITUDE	AIRMASS
1	-13.7042	1.5912	-12.9854	1.5927	-10.4869	1.5942	-100.0000	0.0000	-100.0000	0.0000	-100.0000	0.0000
2	-13.6668	1.7238	-12.9267	1.7256	-10.4168	1.7275	-100.0000	0.0000	-100.0000	0.0000	-100.0000	0.0000
3	-13.6505	1.9059	-12.8959	1.9082	-10.3730	1.9105	-100.0000	0.0000	-100.0000	0.0000	-100.0000	0.0000
4	-13.6209	2.0365	-12.8504	2.0392	-10.3328	2.0419	-100.0000	0.0000	-100.0000	0.0000	-100.0000	0.0000
5	-13.5141	2.6359	-12.6979	2.6406	-10.1157	2.6453	-100.0000	0.0000	-100.0000	0.0000	-100.0000	0.0000

BB04. 60" APERTURE. TUBE 1. 1120V. 141
1950ALPHA-SCORPII 01 M2 I 0.89 1.83 1.34
COLOUR NO. 1
DATE: 21 9 77

PLOT OF COLOUR 1 (V)



PT.NO.	STAR MAG.	AIRMASS
1	-13.7042	1.5912
2	-13.6668	1.7238
3	-13.6505	1.9059
4	-13.6209	2.0365
5	-13.5141	2.6359

8804. 60" APERTURE. TUBE 1. 1120V. 141
1950ALPHA-SCORPII 01 M2 I 0.89 1.83 1.34

COLOUR NO 1
DATE: 21 9 77
L-R OF COLOUR 1 (V)

DATA FOR LINEAR REGRESSION:

PT. NO.	X VALUE	Y VALUE	WEIGHT ASSIGNED ≈ 1/X
1	1.5912	-13.7042	0.6285
2	1.7238	-13.6668	0.5801
3	1.9059	-13.6505	0.5247
4	2.0365	-13.6209	0.4910
5	2.6359	-13.5141	0.3794

EXTINCTION COEFF:

slope

STELLAR MAGNITUDES PER AIRMASS: 0.1773 +OR- 0.0100
NEPERS PER AIRMASS: 0.1633 +OR- 0.0092 ⟶ slope/1.0857

ZERO AIRMASS INTERCEPT= -13.9822 +OR- 0.0194

N= 5

NORMALIZED STD ERR OF ESTIMATE=0.00577

CORRELATION COEFF=0.99530

QUANTITY:	X	Y	X**2	Y**2	XY
WEIGHTED AV:	1.9203497	-13.6416338	3.7996921	186.0977279	-26.1768544