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MEMORANDUM

TO: Dr. Thomas Broadhead, Director
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FROM: Kermit E. Duckett

K.E. Duckett

DATE: November 29, 1994

SUBJECT: Undergraduate Honors Thesis by Christopher Stone

This is to confirm that Christopher Michael Stone has completed his senior honors thesis under my supervision and to my satisfaction. His project, *Lab Exercise in Photoelectric Photometry for Astronomy 217-218*, was carried out in substantive detail. The final paper submitted to me demonstrated Chris' ability to select a meaningful experiment in astronomy, to research the literature and to organize his thoughts for carrying out the steps necessary to reach a conclusion, to complete the experiment, and to record the results in a clear and concise manner. Furthermore, he was able to reduce the complete work to an evening laboratory exercise for the students in Honors Astronomy. His project has been a valuable contribution to our laboratory-based astronomy courses through its linkage to "real, hands-on" experimental astronomy. It is likely that this exercise, as written for undergraduate students, will become a standard laboratory exercise in the astronomy manual for introductory astronomy students. It will certainly become a component of the honors astronomy course requirements.

I would hope that Chris' thesis has provided the challenge expected of seniors in the University Honors Program. It has been my pleasure to work with him and to connect in this way with the honors programs of UTK.

cc: C. Stone

**Lab Exercise in
Photoelectric Photometry
for Astronomy 217-218**

Christopher Michael Stone

December 2, 1994

Supervised by
Dr. Kermit Duckett

Introduction

The purpose of this exercise is to familiarize the student with the basic practices of UBV photometry without the bogging mathematical calculations. Photometry is the practice of measuring the apparent brightness of a stellar object and converting that brightness to a common scale. The basic techniques for data collection will be practiced as will a brief exercise in data reduction, which is the process of changing the readings an observer makes into a general scale of brightness. The main goal of this experiment is to give the student insight into how star magnitudes are determined.

Background

Hipparchus (circa 160-127 B.C.) was the first to attempt to classify stars according to their observed brightness. He listed the brightest stars in the sky as of being of magnitude 1. The stars a little dimmer than those deemed as magnitude 1 were classified as magnitude 2, and so forth. Hipparchus recorded stars as dim as magnitude 6 with the naked eye, and his scale is still used today, albeit in a much more precise manner. There are two types of photometry that are widely practiced today, differential and UBV photometry. UBV photometry uses a digital or analog photometer to measure the intensity of a star over a given time interval, usually 1 or 10 seconds. Optical filters are placed in the starlight's path into the photometer to accurately measure the intensity of the incoming light at various wavelengths. This is important in several respects, one of the most important being that one can determine the temperature of a star by the wavelength of light which it emits (via the Stefan-Boltzmann Law). The intensities of these various wavelengths of the incoming starlight can then be used to calculate the **apparent instrumental magnitude** of the particular star. This is equivalent to the way the star looks to the instrument, without any mathematical corrections. Next one has to subtract from this reading the **background magnitude**, which is the amount of background light that is present near the position of the measured star. This will result in the **instrumental magnitude** of the star in question, which is the magnitude of the star, according to Hipparchus' modified scale and according to the instrument one is using.

Next one must make corrections for the fact that since the light is coming from deep space, it must first pass through our atmosphere before reaching us. The molecules and atoms in the air interfere and tend to scatter starlight. However we can adjust our results to account for this by calculating the **extinction coefficients** for the sky's general conditions at the time of observation. For highly precise photometry, extinction coefficients should be calculated for every star one measures at roughly the same time that one takes the reading on the star, or the **natural magnitude**, as it is sometimes called.

Once one has corrected his or her data for atmospheric extinction, the resulting magnitude is that which the instrument would see roughly if it were above the earth's atmosphere looking at the same star. However, one can easily see that different instruments could give different readings for the same star on the same night in the same location. Minute fluctuations in the construction of each instrument lead to uncertainties in the measurements made from that instrument. Therefore the last step of our process is to convert our natural magnitudes to standard UVB scale, which is the standard method used to classify stars by their intensities. Hence, the **standard magnitude** of the star is the ultimate goal of this exercise.

Procedure

After the lab instructor gives a brief overview of the photometer and telescope to be used, select a star to use for data collection. Make sure you know the star's name, etc., because this information is vital to latter portions of the exercise. Record this one the answer sheet.

Name of star: _____

Once one is ready to begin his or her data collection, record the starting time.

Starting time: _____

Now, make sure the V-Filter is properly inserted into the photometer, and line the telescope with the star you have selected. **Do not hesitate to ask for assistance!** Use the scaling factor on the photometer that gives you the best accuracy without "flooding" the instrument. Using one-second intervals, make 5-10 recordings from the photometer, making sure that the photometer is precisely on the correct star. **Be sure to record the scale factor!** Write all data on the answer sheet.

Moving the telescope slightly off the star in question, record 5-10 readings from the photometer, again being careful to select and record the scale factor properly. This data will serve as our background measurement. Record background data on answer sheet.

Repeat the above steps for different filters should the lab instructor wish you to do so.

After all data collection is complete, record the finish time for the readings.

Finish time: _____

Now, return to the lab and let the instructor give an overview of "The Sky," a software package belonging to the physics and astronomy department. Using the start and finish times you recorded on the roof, calculate the mid-observation time. For example, if one starts at 7:45 and finishes at 7:55, then the median time is 7:50. Times to the nearest minute are fine. Enter your median time into "The Sky" and then search for your star, recording its altitude as given by the program. Note that it will be necessary to convert DMS into degrees.

Altitude: _____

Next, we need to calculate the zenith angle for the observed star. The zenith angle is that angle which the observed star makes with the zenith and the observer. A star at the horizon would have a zenith angle very near 90° , while the North Star has a zenith angle near 54° . The conversion from altitude to zenith is as follows:

$$Z = 90^\circ - \text{altitude}$$

$$Z = \underline{\hspace{2cm}}$$

From the zenith angle, we next calculate the **airmass**, which is a relative measurement of "how much air" the light from the star must pass through to get to the observer. Light from stars near the zenith pass through less air than those observed near the horizon. The formula for calculating the airmass is as follows:

$$X = \frac{1}{\cos(Z)}$$

where Z is the zenith angle calculated above. Record the airmass of your star on the answer sheet.

$$X = \underline{\hspace{2cm}}$$

Next, average the 5-10 readings that were taken on the roof for the star, then average the 5-10 readings taken for the background. Record these averages on the answer sheet.

$$S_{\text{avg}} = \underline{\hspace{2cm}}$$

$$B_{\text{avg}} = \underline{\hspace{2cm}}$$

Next, subtract S_{avg} from B_{avg} , and divide the average by the scale factor. Record this on the answer sheet.

$$\begin{aligned} v(S_{avg} - B_{avg}) &= \underline{\hspace{2cm}} \\ u(S_{avg} - B_{avg}) &= \underline{\hspace{2cm}} \\ b(S_{avg} - B_{avg}) &= \underline{\hspace{2cm}} \end{aligned}$$

Now we shall calculate the **apparent magnitude** of our observed star. For the V-Filter, we use the following formula:

$$v = -2.5 \log_{10}(S_{avg} - B_{avg}) + 7.450$$

(NOTE: If one is using the U and B filters also, then the difference between the background and star readings is done as above, but the equations for the respective magnitudes are different:

$$u = -2.5 \log_{10}(S_{avg} - B_{avg}) + 4.250$$

$$b = -2.5 \log_{10}(S_{avg} - B_{avg}) + 7.250$$

The magnitudes usually recorded in star charts are the **u-b** and **b-v** magnitudes, which can be determined by combining the appropriate equations above.)

Next, we need to correct our results for **atmospheric extinction**. The equations that allows us to do this is as follows:

$$\begin{aligned} v_0 &= v - k_v'X \\ u_0 &= u - k_u'X \\ b_0 &= b - k_b'X \\ (u-b)_0 &= (u-b) - k_{ub}'X \\ (b-v)_0 &= (b-v) - k_{bv}'X \end{aligned}$$

where the k' values are the **extinction coefficients**, X is the airmass calculated above, and v_0 , u_0 , etcetera are the **natural magnitude**. For our purposes, the k' values are given below.

$$\begin{aligned} k_v' &= 0.1679 \\ k_u' &= 0.5331 \\ k_b' &= 0.4080 \\ k_{ub}' &= 0.2401 \\ k_{bv}' &= 0.1251 \end{aligned}$$

Thus, we have calculated the magnitude that our instrument would give for the observed star should the observation take place above the atmosphere.

Finally, we must convert our magnitude(s) into standard scale. This is done by following the formula listed below.

$$V - v_0 = \zeta_v$$

$$(B-V) - (b-v)_0 = \zeta_{bv}$$

$$(U-B) - (u-b)_0 = \zeta_{ub}$$

where V , $(B-V)$, and $(U-B)$ are the **standard magnitudes** of a given star listed in star catalogs, etc. The terms ζ_v , ζ_{bv} , and ζ_{ub} are the **transformation coefficients** and have the following values:

$$\zeta_v = -0.0358$$

$$\zeta_{bv} = -0.0737$$

$$\zeta_{ub} = 0.0071$$

Now, we have calculated the magnitude value(s) that should appear in a star catalog. Let's now find the nominal value(s) and see how close we came.

$$\begin{array}{rcl} V' = \underline{\hspace{2cm}} & V = \underline{\hspace{2cm}} \\ (B-V)' = \underline{\hspace{2cm}} & (B-V) = \underline{\hspace{2cm}} \\ (U-B)' = \underline{\hspace{2cm}} & (U-B) = \underline{\hspace{2cm}} \end{array}$$

where the primed values are those found in the catalog, and the unprimed values are those calculated here. If everything works well, the calculated values should be within 0.2 mag from the nominal values in the catalog.

Answer Sheet

Star _____
 Start time _____
 Finish time _____
 Median time _____

V-Filter

Star Scale=	Background Scale=
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.

U-Filter

Star Scale=	Background Scale=
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.

B-Filter

Star Scale=	Background Scale=
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.

Altitude = _____

Z = _____

X = _____

$v(S_{avg} - B_{avg}) =$ _____

$u(S_{avg} - B_{avg}) =$ _____

$b(S_{avg} - B_{avg}) =$ _____

v = _____

u = _____

b = _____

b-v = _____

u-b = _____

$v_0 =$ _____

$u_0 =$ _____

$b_0 =$ _____

$(b-v)_0 =$ _____

$(u-b)_0 =$ _____

V = _____

U = _____

B = _____

(B-V) = _____

(U-B) = _____

Apparatus

The equipment I used to verify the results of this exercise is the same that the students themselves will use. A Celestron 8 telescope is attached to an Optec SSP-3 photoelectric photometer, while the data collected was recorded by hand. All regression analysis and final compilation of the material in this report was completed using a standard IBM-compatible computer equipped with MicroSoft Office and a Hewlett-Packard 550C color printer.

Data Collection

The data collected for this report was done over a span of one-month. A total of 10 hours of actual collection took place over this time. A month was necessary for completion of the data collection due to the fact that ideal weather was mandatory for quality data. Also, no more than two or three stars could be recorded per night due to conflicting work and school schedules. Ideally, all data should be taken in one evening. However, I feel as though I have shown that reasonable results can be obtained if the data is collected over a longer span of time, since the coefficients used to reduce the data remain virtually constant from night to night, given that all observation nights are relatively clear.

I collected data on eleven different stars during this time, with at least 10 1 second intervals recorded for each filter (C, V, U, B) on both the star and the sky background. I found out after the collection was completed that the C filter was not necessary for this exercise, but that data is still reproduced here. Also, two stars that I collected data on did not yield good results when their magnitudes were calculated, which I attribute to error on my part in recording the data. Hence, those stars do not appear in the worksheet where I calculate the extinction and transformation coefficients.

Approximations

In writing this lab exercise, I was forced to make some approximations in the calculations in order to make the lab less involved for the students. If the exercise were left to its original complexity, it could not be completed in the two-hour timeframe necessary.

Calculation of the apparent magnitudes

The equation which yields the apparent magnitude of a given star using a given filter is as follows:

$$M = -2.5\log_{10}(\text{reading average}) + \text{constant}$$

where the "reading average" is simply the average of all the 1 second iterations recorded divided by the scale factor used on the photometer. The constant is something to be determined.

The constant was arrived at by plugging a star whose magnitude was known into the above equation. In this case, I used Markab. I used the average of my own data, and the apparent magnitude of Markab and solved for the constant, which turned out to be 7.460. Entering this into the spreadsheet along with the magnitudes of the other observed stars, I changed the constant until I found the one value which gave a minimum of error between the nominal and experimental values for all stars recorded. This can be seen as the top portion of the page titled "Various Coefficient Calculations." The same was done for the U and B filters as well, which can be seen as the bottom portion of the same page. The resulting values are recorded as the "u constant," "v constant," and the "b constant" on said page.

Calculating Extinction Coefficients

The equation that allows us to calculate the atmospheric extinction coefficients is as follows:

$$M = M_0 - k'X$$

where M is the nominal magnitude of a given filter, M_0 is the measured magnitude, k' is the extinction coefficient and X is the airmass at the zenith angle where the observed star is located at mid-observation. Ideally, a number of stars of varying airmasses should be observed within a small increment of time, with a linear regression yielding the extinction coefficient. However, if all observations are made from the same location, the extinction coefficient does not change much from night to night. Also, a median value for k' would suit the lab exercise better, since it would more closely approximate the sky conditions that the students would have when they do this exercise. Granted, the students themselves could find the k' for their observation time. However, time constraints would not allow this. Furthermore, the students may not be familiar with regression analysis, which would place an extra burden upon the lab instructor.

In any case, I took the difference between the calculated magnitudes I found and the nominal magnitudes and plotted them against the respective airmasses at which the calculations were made. rearranging the last equation yields:

$$M - M_0 = -k'X$$

which is simply an equation for a straight line whose slope is $-k'$ and whose intercept is zero. Thus, a linear regression of the graph described above with the intercept of the line-fit forced to be zero gave a slope which turned out to be $-k'$. This was done for the V, U, and B filters, with each respective regression reproduced later in this report. One problem I encountered while calculating the extinction coefficients for the U and B filters was that I could only find nominal values for these filters on three stars that I had recorded. Optimally, the regressions for these filters should have been done on all nine stars, but I simply could not locate a table including these values. Obviously, a more rigorous treatment of extinction could have been done, but would have only changed the resulting k 's by less than 1%, and were omitted.

Calculating Transformation Coefficients

The final set of coefficients calculated were those which transformed the natural magnitudes to those on the standard scale. The equations which govern this are as follows:

$$V - v_0 = \zeta_v$$

$$(B-V) - (b-v)_0 = \zeta_{bv}$$

$$(U-B) - (u-b)_0 = \zeta_{ub}$$

Obviously, this is merely reflecting the difference between the nominal values for each filter and the calculated values. The values that I arrived at for the respective ζ 's were the respective averages of the differences between nominal and experimental for each filter over the nine stars recorded on the "Calculating Various Coefficients" worksheet.

I must stress that it was very difficult to find a way to shorten this exercise while maintaining as much accuracy as possible. I gave as much care and consideration into calculating nominal values for the extinction and transformation coefficients as possible while not jeopardizing precision and accuracy. A more thorough treatment of this exercise could be done for a higher-level class, but I feel that the results I present here are as close to ideal as possible for the students of Honors Astronomy 217-218.

Data and Analysis

In the pages to follow are the raw data I collected for this exercise (organized by stars), the worksheet for calculating the extinction and transformation coefficients, and the extinction regressions for each filter. You will see in the data tables that I took two full sets of readings on Deneb. I did this to check the validity of the data I was collecting. My values turned out to be fairly trustworthy, and therefore the values for Deneb appearing in the coefficients worksheet are merely the average of the magnitudes, etc. that I calculated from the separate data sets.

e Pegasus 10/6/94 9pm

Data multiplied by scale
factors

Instrumental Magnitudes

C-Filter

Background 10 scale	Star 1 scale	B	S
111	2197	11.1	2197
110	2202	11	2202
111	2145	11.1	2145
110	2176	11	2176
112	2197	11.2	2197
111	2171	11.1	2171
110	2140	11	2140
109	2204	10.9	2204
108	2184	10.8	2184
107	2162	10.7	2162

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	4.828	16.906	1.545012437
v	6.202	382.36	1.011574243
b	5.368	214.12	1.450923387
u-b	-0.54	-197.214	0.094089049
b-v	-0.834	-57	0.439349144

U-filter

Background 100 scale	Star 100 scale	B	S
478	1687	4.78	16.87
483	1671	4.83	16.71
482	1714	4.82	17.14
482	1686	4.82	16.86
482	1675	4.82	16.75
489	1692	4.89	16.92
481	1680	4.81	16.8
488	1709	4.88	17.09
482	1696	4.82	16.96
481	1696	4.81	16.96

V-filter

Background 100 scale	Star 10 scale	B	S
617	3842	6.17	384.2
620	3863	6.2	386.3
622	3769	6.22	376.9
628	3829	6.28	382.9
621	3866	6.21	386.6
624	3816	6.24	381.6
617	3794	6.17	379.4
618	3791	6.18	379.1
619	3826	6.19	382.6
616	3840	6.16	384

B-filter

Background 100 scale	Star 10 scale	B	S
537	2086	5.37	208.6
540	2168	5.4	216.8
539	2155	5.39	215.5
538	2150	5.38	215
536	2180	5.36	218
533	2125	5.33	212.5
539	2136	5.39	213.6
535	2154	5.35	215.4
540	2142	5.4	214.2
531	2116	5.31	211.6

n Pegasus

9pm 10/13/94

Instrumental Magnitudes

B-Filter

Data multiplied by scale
factors

Background 100 scale	Star 100 scale	B	S
536	2729	5.36	27.29
528	2702	5.28	27.02
534	2706	5.34	27.06
534	2702	5.34	27.02
530	2730	5.3	27.3
531	2698	5.31	26.98
534	2739	5.34	27.39
526	2694	5.26	26.94
524	2704	5.24	27.04
529	2736	5.29	27.36

Filter	B	S	$[2.5 \cdot \log(M(S-B))] - 1$
u	5.715	67.18	-0.221569715
v	4.935	5.82	7.582641823
b	7.984	438.9	0.66401845
u-b	-2.269	-371.72	-0.885588165
b-v	3.049	433.08	-6.918623373

V-Filter

Background 100 scale	Star 10 scale	B	S
571	686	5.71	68.6
575	666	5.75	66.6
576	681	5.76	68.1
575	670	5.75	67
573	675	5.73	67.5
570	661	5.7	66.1
565	672	5.65	67.2
571	660	5.71	66
570	675	5.7	67.5
569	672	5.69	67.2

U-Filter

Background 100 scale	Star 100 scale	B	S
493	581	4.93	5.81
491	579	4.91	5.79
487	588	4.87	5.88
493	586	4.93	5.86
495	584	4.95	5.84
493	585	4.93	5.85
497	580	4.97	5.8
499	580	4.99	5.8
497	575	4.97	5.75
490	582	4.9	5.82

C-Filter

Background 100 scale	Star 1 scale	B	S
808	440	8.08	440
807	441	8.07	441
800	440	8	440
800	438	8	438
795	437	7.95	437
795	433	7.95	433
790	435	7.9	435
794	438	7.94	438
795	446	7.95	446
800	441	8	441

Vega

9:30pm 10/24/94

Instrumental Magnitudes

C-filter

Data multiplied by scale
factors

Background 10 scale	Star 1 scale	B	S
110	4961	11	4961
110	4868	11	4868
107	4839	10.7	4839
108	4886	10.8	4886
107	4930	10.7	4930
108	4909	10.8	4909
106	4844	10.6	4844
107	4979	10.7	4979
106	4948	10.6	4948
106	4937	10.6	4937

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	4.76	43.31	0.284939044
v	6.323	910.8	0.059006181
b	5.353	610.3	0.295706682
u-b	-0.593	-566.99	-0.010767638
b-v	-0.97	-300.5	0.236700501

U-filter

Background 100 scale	Star 10 scale	B	S
474	436	4.74	43.6
476	420	4.76	42
478	428	4.78	42.8
476	440	4.76	44
474	428	4.74	42.8
476	432	4.76	43.2
473	436	4.73	43.6
480	440	4.8	44
475	432	4.75	43.2
478	439	4.78	43.9

V-filter

Background 100 scale	Star 1 scale	B	S
635	918	6.35	918
628	921	6.28	921
632	909	6.32	909
633	889	6.33	889
634	924	6.34	924
631	912	6.31	912
634	919	6.34	919
633	907	6.33	907
629	910	6.29	910
634	899	6.34	899

B-filter

Background 100 scale	Star 1 scale	B	S
535	613	5.35	613
541	603	5.41	603
542	602	5.42	602
536	613	5.36	613
535	604	5.35	604
535	622	5.35	622
532	615	5.32	615
535	616	5.35	616
532	608	5.32	608
530	607	5.3	607

Tarazed

9pm 10/26/94

C-filter

Background 100 scale	Star 1 scale	Data multiplied by scale factors	
		B	S
1024	706	10.24	706
1020	711	10.2	711
1023	705	10.23	705
1028	706	10.28	706
1018	704	10.18	704
1017	703	10.17	703
1022	706	10.22	706
1024	705	10.24	705
1022	713	10.22	713
1024	706	10.24	706

Instrumental Magnitudes

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	5.017	5.178	6.23293531
v	6.031	74.49	2.861423623
b	5.316	17.993	4.492458774
u-b	-0.299	-12.815	1.740476536
b-v	-0.715	-56.497	1.631035152

U-filter

Background 100 scale	Star 100 scale	B	S
499	510	4.99	5.1
504	519	5.04	5.19
502	517	5.02	5.17
501	518	5.01	5.18
503	516	5.03	5.16
502	520	5.02	5.2
502	516	5.02	5.16
503	525	5.03	5.25
501	518	5.01	5.18
500	519	5	5.19

V-filter

Background 100 scale	Star 10 scale	B	S
602	740	6.02	74
604	741	6.04	74.1
603	751	6.03	75.1
601	733	6.01	73.3
600	741	6	74.1
605	742	6.05	74.2
600	755	6	75.5
605	749	6.05	74.9
609	749	6.09	74.9
602	748	6.02	74.8

B-filter

Background 100 scale	Star 100 scale	B	S
532	1810	5.32	18.1
532	1800	5.32	18
533	1769	5.33	17.69
528	1810	5.28	18.1
532	1777	5.32	17.77
529	1796	5.29	17.96
537	1798	5.37	17.98
530	1802	5.3	18.02
532	1818	5.32	18.18
531	1813	5.31	18.13

Markab

10:30pm 10/26/94

Instrumental Magnitudes

C-Filter

Data multiplied by scale
factors

Background 100 scale	Star 1 scale	B	S
877	494	8.77	494
878	498	8.78	498
876	490	8.76	490
877	508	8.77	508
878	499	8.78	499
874	493	8.74	493
875	508	8.75	508
878	492	8.78	492
880	502	8.8	502
872	500	8.72	500

Filter	B	S	$[2.5 \cdot \log(M(S-B))]*-1$
u	5.098	9.909	2.544411608
v	5.793	97.91	2.539150536
b	5.322	72.83	2.676611896
u-b	-0.224	-62.921	-0.132200288
b-v	-0.471	-25.08	0.13746136

U-Filter

Background 100 scale	Star 100 scale	B	S
506	992	5.06	9.92
507	993	5.07	9.93
511	998	5.11	9.98
514	994	5.14	9.94
510	996	5.1	9.96
508	998	5.08	9.98
512	958	5.12	9.58
509	997	5.09	9.97
511	992	5.11	9.92
510	991	5.1	9.91

V-Filter

Background 100 scale	Star 10 scale	B	S
580	973	5.8	97.3
578	963	5.78	96.3
576	991	5.76	99.1
578	971	5.78	97.1
579	974	5.79	97.4
582	975	5.82	97.5
584	986	5.84	98.6
580	977	5.8	97.7
578	994	5.78	99.4
578	987	5.78	98.7

B-Filter

Background 100 scale	Star 10 scale	B	S
533	728	5.33	72.8
534	715	5.34	71.5
530	720	5.3	72
533	732	5.33	73.2
531	728	5.31	72.8
532	729	5.32	72.9
531	736	5.31	73.6
530	733	5.3	73.3
534	732	5.34	73.2
534	730	5.34	73

Alpheratz

9:45pm 10/28/94

Instrumental Magnitudes

C-filter

Data multiplied by scale
factors

Background 100 scale	Star 1 scale	B	S
870	684	8.7	684
876	666	8.76	666
868	674	8.68	674
873	679	8.73	679
870	676	8.7	676
879	680	8.79	680
875	686	8.75	686
876	690	8.76	690
880	689	8.8	689
879	687	8.79	687

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	4.994	13.426	1.935173505
v	5.717	134.21	2.177801328
b	5.233	100.55	2.302074088
u-b	-0.239	-87.124	-0.366900582
b-v	-0.484	-33.66	0.12427276

U-filter

Background 100 scale	Star 100 scale	B	S
501	1343	5.01	13.43
491	1342	4.91	13.42
499	1333	4.99	13.33
501	1347	5.01	13.47
501	1331	5.01	13.31
499	1338	4.99	13.38
503	1336	5.03	13.36
498	1354	4.98	13.54
499	1357	4.99	13.57
502	1345	5.02	13.45

V-filter

Background 100 scale	Star 10 scale	B	S
571	1319	5.71	131.9
582	1326	5.82	132.6
578	1342	5.78	134.2
569	1335	5.69	133.5
564	1350	5.64	135
575	1335	5.75	133.5
568	1353	5.68	135.3
570	1336	5.7	133.6
567	1375	5.67	137.5
573	1350	5.73	135

B-filter

Background 100 scale	Star 10 scale	B	S
527	1005	5.27	100.5
523	1003	5.23	100.3
524	997	5.24	99.7
523	1012	5.23	101.2
522	1000	5.22	100
520	1001	5.2	100.1
524	1019	5.24	101.9
520	1012	5.2	101.2
525	1005	5.25	100.5
525	1001	5.25	100.1

Algenib

10:15pm 10/28/94

Instrumental Magnitudes

C-filter

Data multiplied by scale
factors

Background 100 scale	Star 1 scale	B	S
892	321	4.46	321
885	321	4.425	321
889	323	4.445	323
889	319	4.445	319
890	327	4.45	327
889	323	4.445	323
893	321	4.465	321
891	321	4.455	321
887	329	4.435	329
890	320	4.45	320

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	5.053	10.676	2.375079791
v	5.845	66.03	3.001279338
b	5.302	55.47	2.998933031
u-b	-0.249	-44.794	-0.623853239
b-v	-0.543	-10.56	-0.002346307

U-filter

Background 100 scale	Star 100 scale	B	S
506	1071	5.06	10.71
503	1065	5.03	10.65
507	1056	5.07	10.56
506	1069	5.06	10.69
501	1070	5.01	10.7
512	1074	5.12	10.74
505	1062	5.05	10.62
502	1064	5.02	10.64
506	1070	5.06	10.7
505	1075	5.05	10.75

V-filter

Background 100 scale	Star 10 scale	B	S
584	665	5.84	66.5
586	667	5.86	66.7
582	654	5.82	65.4
586	659	5.86	65.9
588	664	5.88	66.4
582	666	5.82	66.6
585	645	5.85	64.5
583	655	5.83	65.5
584	658	5.84	65.8
585	670	5.85	67

B-filter

Background 100 scale	Star 10 scale	B	S
532	560	5.32	56
534	561	5.34	56.1
530	550	5.3	55
527	553	5.27	55.3
527	545	5.27	54.5
534	567	5.34	56.7
529	551	5.29	55.1
527	544	5.27	54.4
532	560	5.32	56
530	556	5.3	55.6

Deneb (2)

9:30pm 11/17/94

Instrumental Magnitudes

C-filter

Data multiplied by scale
factors

Background 100 scale	Star 1 scale	B	S
1180	1453	11.8	1453
1179	1471	11.79	1471
1176	1435	11.76	1435
1172	1441	11.72	1441
1171	1450	11.71	1450
1168	1463	11.68	1463
1168	1464	11.68	1464
1168	1461	11.68	1461
1172	1449	11.72	1449
1171	1449	11.71	1449

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	4.93	18.425	1.424567778
v	6.366	267.8	1.406594831
b	5.54	170.35	1.707541102
u-b	-0.61	-151.925	-0.282973324
b-v	-0.826	-97.45	0.300946271

U-filter

Background 100 scale	Star 100 scale		
495	1849	4.95	18.49
487	1808	4.87	18.08
496	1855	4.96	18.55
494	1795	4.94	17.95
500	1871	5	18.71
493	1834	4.93	18.34
489	1857	4.89	18.57
488	1875	4.88	18.75
495	1847	4.95	18.47
493	1834	4.93	18.34

V-filter

Background 100 scale	Star 1 scale		
638	264	6.38	264
631	262	6.31	262
640	275	6.4	275
639	270	6.39	270
635	262	6.35	262
636	261	6.36	261
640	262	6.4	262
634	265	6.34	265
628	282	6.28	282
645	275	6.45	275

B-filter

Background 100 scale	Star 10 scale		
554	1706	5.54	170.6
556	1674	5.56	167.4
552	1705	5.52	170.5
551	1647	5.51	164.7
552	1717	5.52	171.7
557	1677	5.57	167.7
555	1719	5.55	171.9
557	1769	5.57	176.9
554	1715	5.54	171.5
552	1706	5.52	170.6

Sadr

9:45pm 11/17/94

Instrumental Magnitudes

C-filter

Data multiplied by scale
factors

Background 100 scale	Star 1 scale	B	S
1244	714	12.44	714
1251	668	12.51	668
1245	689	12.45	689
1244	680	12.44	680
1250	677	12.5	677
1247	689	12.47	689
1243	696	12.43	696
1244	692	12.44	692
1249	654	12.49	654
1241	688	12.41	688

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	5.022	6.588	3.763020606
v	6.5	113.84	2.373096023
b	5.606	45.4	3.250456011
u-b	-0.584	-38.812	0.512564595
b-v	-0.894	-68.44	0.877359988

U-filter

Background 100 scale	Star 100 scale	B	S
505	672	5.05	6.72
502	661	5.02	6.61
499	667	4.99	6.67
505	657	5.05	6.57
505	659	5.05	6.59
504	649	5.04	6.49
503	663	5.03	6.63
497	650	4.97	6.5
499	657	4.99	6.57
503	653	5.03	6.53

V-filter

Background 100 scale	Star 10 scale	B	S
648	1146	6.48	114.6
651	1148	6.51	114.8
650	1110	6.5	111
654	1138	6.54	113.8
652	1138	6.52	113.8
646	1144	6.46	114.4
655	1137	6.55	113.7
645	1153	6.45	115.3
648	1115	6.48	111.5
651	1155	6.51	115.5

B-filter

Background 100 scale	Star 10 scale	B	S
561	456	5.61	45.6
559	450	5.59	45
560	453	5.6	45.3
559	449	5.59	44.9
564	457	5.64	45.7
559	448	5.59	44.8
560	445	5.6	44.5
564	460	5.64	46
558	470	5.58	47
562	452	5.62	45.2

Deneb

7:30pm 11/18/94

Instrumental Magnitudes

C-filter

Data multiplied by scale
factors

Background 100 scale	Star 1 scale	B	S
1353	1344	13.53	1344
1315	1363	13.15	1363
1327	1375	13.27	1375
1334	1357	13.34	1357
1351	1356	13.51	1356
1349	1354	13.49	1354
1340	1342	13.4	1342
1336	1340	13.36	1340
1345	1350	13.45	1350
1330	1336	13.3	1336

Filter	B	S	$[2.5 \cdot \log(M(S-B))] \cdot -1$
u	5.022	17.234	1.533033011
v	6.432	233	1.562003573
b	5.483	147.12	1.872058201
u-b	-0.461	-129.886	-0.33902519
b-v	-0.949	-85.88	0.310054629

U-filter

Background 100 scale	Star 100 scale	B	S
500	1720	5	17.2
501	1676	5.01	16.76
500	1681	5	16.81
501	1700	5.01	17
506	1740	5.06	17.4
505	1765	5.05	17.65
503	1738	5.03	17.38
502	1753	5.02	17.53
501	1741	5.01	17.41
503	1720	5.03	17.2

V-filter

Background 100 scale	Star 1 scale	B	S
646	233	6.46	233
641	232	6.41	232
646	238	6.46	238
645	232	6.45	232
644	229	6.44	229
640	231	6.4	231
642	233	6.42	233
645	235	6.45	235
643	236	6.43	236
640	231	6.4	231

B-filter

Background 100 scale	Star 10 scale	B	S
547	1478	5.47	147.8
544	1476	5.44	147.6
548	1457	5.48	145.7
555	1497	5.55	149.7
550	1454	5.5	145.4
546	1460	5.46	146
550	1480	5.5	148
548	1472	5.48	147.2
549	1464	5.49	146.4
546	1474	5.46	147.4

Altair

7:45pm 11/18/94

Instrumental Magnitudes

C-filter

Data multiplied by scale
factors

Background 100 scale	Star 1 scale		
1940	1692	19.4	1692
1926	1687	19.26	1687
1945	1758	19.45	1758
1944	1705	19.44	1705
1954	1758	19.54	1758
1950	1700	19.5	1700
1970	1737	19.7	1737
1962	1757	19.62	1757
1967	1762	19.67	1762
1950	1740	19.5	1740

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	4.999	12.551	2.054845047
v	7.753	326.4	1.191725415
b	5.843	166.77	1.733427712
u-b	-0.844	-154.219	0.321417335
b-v	-1.91	-159.63	0.541702297

U-filter

Background 100 scale	Star 100 scale		
502	1245	5.02	12.45
501	1237	5.01	12.37
499	1242	4.99	12.42
499	1261	4.99	12.61
494	1274	4.94	12.74
502	1243	5.02	12.43
497	1260	4.97	12.6
503	1269	5.03	12.69
498	1252	4.98	12.52
504	1268	5.04	12.68

V-filter

Background 100 scale	Star 1 scale		
772	332	7.72	332
778	331	7.78	331
771	329	7.71	329
777	323	7.77	323
776	320	7.76	320
772	326	7.72	326
777	326	7.77	326
772	327	7.72	327
783	326	7.83	326
775	324	7.75	324

B-filter

Background 100 scale	Star 10 scale		
582	1652	5.82	165.2
580	1637	5.8	163.7
586	1682	5.86	168.2
584	1658	5.84	165.8
590	1698	5.9	169.8
587	1693	5.87	169.3
589	1650	5.89	165
586	1674	5.86	167.4
579	1673	5.79	167.3
580	1660	5.8	166

Alberio

8pm 11/18/94

Instrumental Magnitudes

C-filter

Data multiplied by scale
factors

Background 100 scale	Star 10 scale	B	S
1782	2318	17.82	231.8
1785	2304	17.85	230.4
1794	2305	17.94	230.5
1798	2357	17.98	235.7
1799	2379	17.99	237.9
1789	2456	17.89	245.6
1790	2351	17.9	235.1
1794	2364	17.94	236.4
1784	2348	17.84	234.8
1785	2320	17.85	232

Filter	B	S	$[2.5 \cdot \log(M(S-B))]^{-1}$
u	5.087	5.251	6.21289038
v	7.69	19.36	4.78232286
b	5.812	8.992	5.9939322
u-b	-0.725	-3.741	0.21895818
b-v	-1.878	-10.368	1.21160934

U-filter

Background 100 scale	Star 100 scale	B	S
507	530	5.07	5.3
509	531	5.09	5.31
503	524	5.03	5.24
513	521	5.13	5.21
506	523	5.06	5.23
514	525	5.14	5.25
505	525	5.05	5.25
515	522	5.15	5.22
508	524	5.08	5.24
507	526	5.07	5.26

V-filter

Background 100 scale	Star 10 scale	B	S
774	178	7.74	17.8
765	201	7.65	20.1
769	186	7.69	18.6
768	203	7.68	20.3
771	214	7.71	21.4
769	206	7.69	20.6
768	198	7.68	19.8
771	171	7.71	17.1
770	189	7.7	18.9
765	190	7.65	19

V-filter

Background 100 scale	Star 100 scale	B	S
575	903	5.75	9.03
581	911	5.81	9.11
586	916	5.86	9.16
580	905	5.8	9.05
577	893	5.77	8.93
582	899	5.82	8.99
584	901	5.84	9.01
581	880	5.81	8.8
586	910	5.86	9.1
580	874	5.8	8.74

Various Coefficient Calculations

	v	Raw b-v	u-b	Nominal V	Air Mass	V-v	w/ ext. corr. v'	Error in v'
Sadr	2.373096	0.87736	0.512565	2.2	1.35	-0.173096	2.14643102	-0.053569
Deneb	1.4842992	0.3055	-0.311	1.25	1.135	-0.234299	1.2937327	0.0437327
Algenib	3.0012793	-0.00235	-0.62385	2.83	1.11	-0.171279	2.81491034	-0.0150897
Markab	2.5391505	0.137461	-0.1322	2.49	1.07	-0.049151	2.35949754	-0.1305025
Tarazed	2.8614236	1.631035	1.740477	2.72	1.25	-0.141424	2.65154862	-0.0684514
Altair	1.1917254	0.541702	0.321417	0.77	1.31	-0.421725	0.97177641	0.20177641
Vega	0.0590062	0.236701	-0.01077	0.04	1.33	-0.019006	-0.16430082	-0.2043008
Alpheratz	2.1778013	0.124273	-0.3669	2.06	1.06	-0.117801	1.99982733	-0.0601727
Alberio	4.7823229	1.211609	0.218958	3.08	1.19	-1.702323	4.58252186	1.50252186

u constant	4.25
v constant	7.45
b constant	7.25

Star	Raw					Nominal U	Nominal B	Air Mass (X)	U-u	B-b	w/ ext. correction		Error in u'	Error in b'	(u-b)'	(b-v)'	Nominal		(U-B)-(u-b)	(B-V)-(b-v)'
	v	u	b	b-v	u-b						u'	b'					B-V	U-B		
Algenib	3.0012793	2.37508	2.998933	-0.00235	-0.6238532	1.73	2.6	1.11	-0.6450798	-0.398933	1.78333879	2.548053	0.053339	-0.05395	-0.76271	0.268857	-0.23	-0.87	-0.10729	-0.49886
Markab	2.5391505	2.544412	2.676612	0.137461	-0.1322003	2.38	2.44	1.07	-0.1644116	-0.236612	1.97399461	2.2400519	-0.40601	-0.19995	-0.26606	0.119446	-0.05	-0.06	0.206057	-0.16945
Altair	1.1917254	2.054845	1.733428	0.541702	0.32141733	1.07	0.99	1.31	-0.984845	-0.743428	1.35648405	1.1989477	0.286484	0.208948	0.157536	-0.22717	0.22	0.08	-0.07754	0.447171

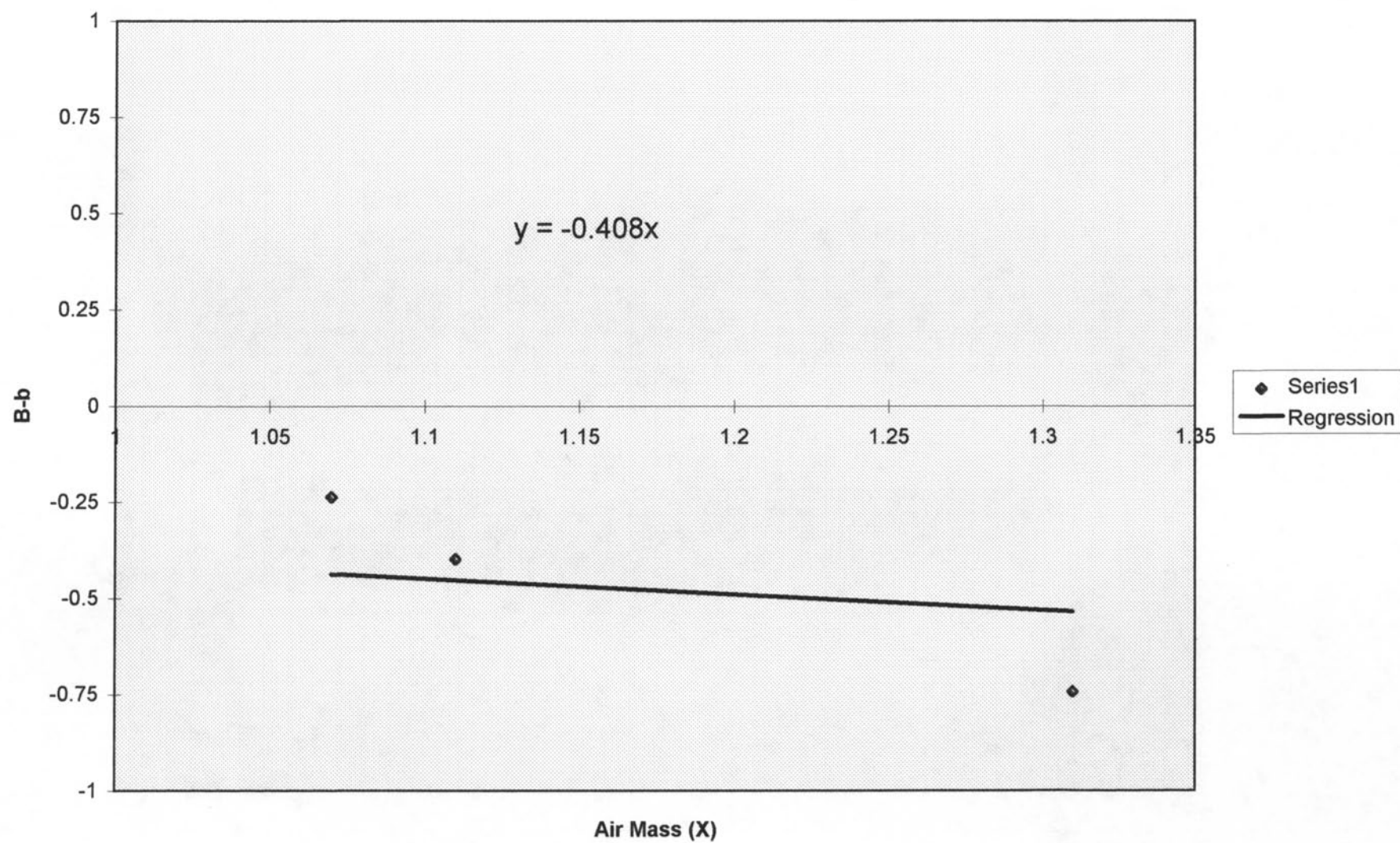
Extinction Coefficients

Kv	0.1879
Ku	0.5331
Kb	0.408
Kbv	0.2401
Kub	0.1251

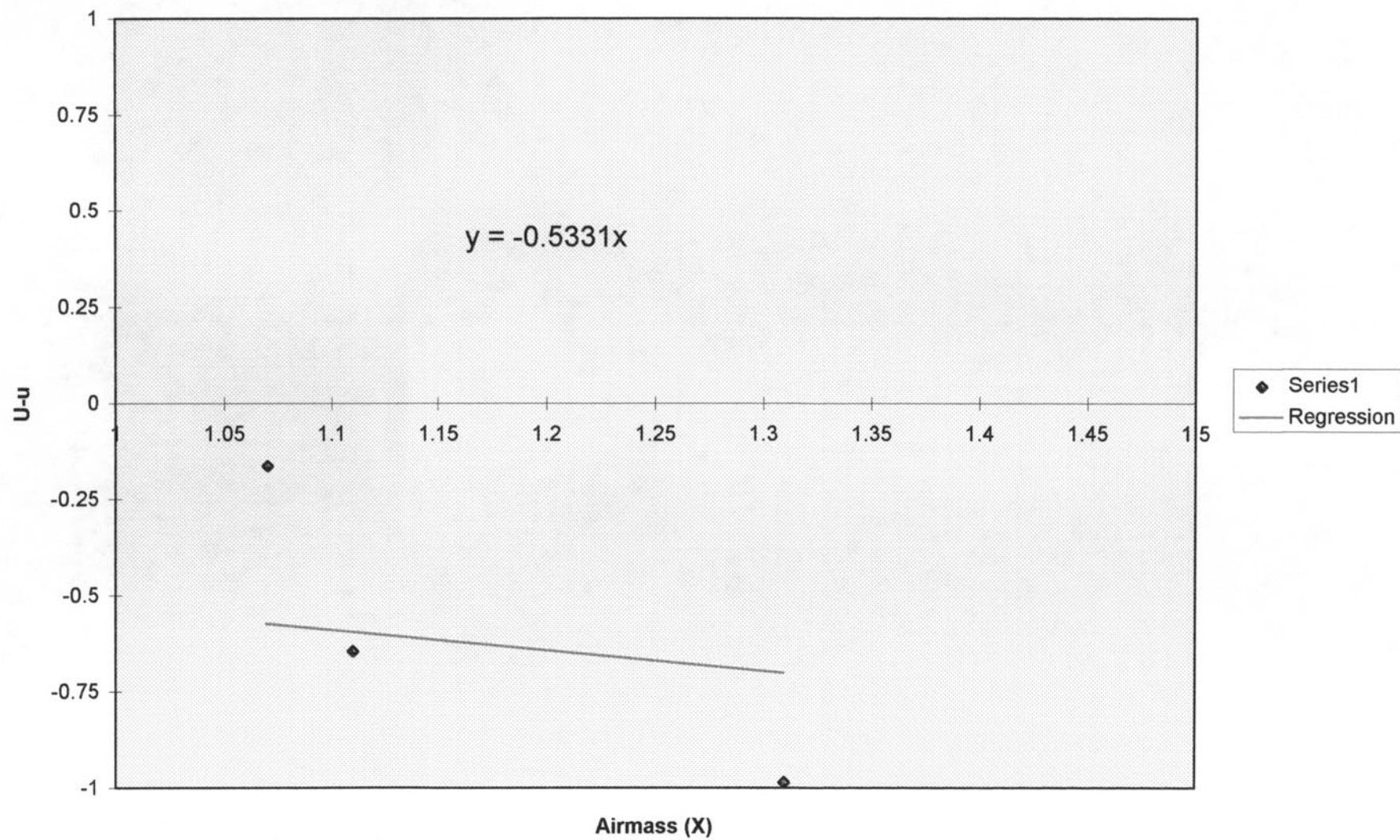
Tranformation Coefficients

Pv	-0.035822
Pbv	-0.073711
Pub	0.0070784

Regression for B-Extinction Coefficient



Regression for U-Extinction Coefficient



Regression for V-Extinction Coefficient

