OPTICAL PHOTOMETRY OF THE

1982-1984

ECLIPSE OF EPSILON AURIGAE

BY

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ABSTRACT

From slightly before the 1982-1984 eclipse of Epsilon Aurigae to the present observers from around the world have been making photoelectric photometry observations of this star system. Over 2000 UBV observations have been reported as well as observations in the R, I, J, H, K, L, M, N, and Q bandpasses plus the y, b, v, and u bandpasses. Twenty nine observers from 9 countries have submitted photometry data to the campaign. The data have shown many interesting features of the star system including a Cepheid-like pulsation, flare activity, mid-eclipse brightening, post egress brightening, plus other strange activity.

I. INTRODUCTION

The purpose of this paper is to report on the optical photometry obtained during the 1982-1984 eclipse of Epsilon Aurigae. Epsilon Aurigae is a third magnitude star located in the charioteer constellation Auriga and is 1900 light years away (Van de Kamp 1978). It is the northern most star, three degrees southeast of Capella, of the three stars that make up a group known as "The Kids". Epsilon Aurigae is an eclipsing star system that has baffled astronomers for over a century. The variability of the system was first noted in 1821 (Fritsch 1824) and the eclipse has been observed continuously ever since. In 1904 the 27.1 year period and two year duration were determined (Ludendroff 1904).

II. THE CAMPAIGN

F.B. Wood organized and coordinated the campaign to study Epsilon Aurigae during the 1955-1957 eclipse. He also suggested a campaign for the 1982-1984 eclipse. R. E. Stencel (NASA), D.S. Hall (DYER OBSERVATORY), and R.M. Genet (FAIRBORN OBSERVATORY) initiated procedures for organizing the present campaign. A campaign newsletter was started to provide rapid distribution of information and observed data during the eclipse. R.E. Stencel published the first two campaign newsletters. Since then the HOPKINS PHOENIX OBSERVATORY has been publishing the newsletters and coordinating the photoelectric photometry data. R.E. Stencel has been providing editorial comment and coordinating the spectroscopy data. J.C. Kemp (UNIVERSITY of OREGON) has been providing the polarimetry reports. To date there have been 12 newsletters published.
These campaign newsletters were partially supported by two small grants from the National Aeronautics and Space Administration which were administered by the American Astronomical Society.

The present campaign has over 80 members with 29 active photoelectric observers. These observers are located all over the world and have provided over 2500 UBVRI data points from before the eclipse until the present. In addition, several observers have provided J, H, K, L, M, N, and Q data plus narrow band y, b, v, and u data.

I wish to express my appreciation to Bob Stencel (NASA) and Paul Schmidtke (KPNO now at Arizona State University) for their encouragement, help, and guidance with the photometry data of Epsilon Aurigae.

III. THE 1982-1984 PHOTOELECTRIC PHOTOMETRY DATA

Most observers used the recommended comparison star lambda Aurigae, however, BD +42 1170, eta Aurigae, and HD 32655 were also used. Most of the observing was done with small telescopes (6" to 18") using photon counting techniques.

Interesting morphological features can be seen in the UBVRI light curves of Epsilon Aurigae. Figure 1 shows a summary of data on Epsilon Aurigae. Figure 2 is a sample of the UBV data base used in the campaign newsletter. Figure 3 shows a composite plot of all Visual PEP data submitted to the campaign as of the beginning of the summer of 1984. There is considerable scattering of data points. Data from the Tjorn Island Astronomical Observatory (TAO) in Sweden, the Hopkins Phoenix Observatory (HPO) in Arizona and the Grim Observatory (GO) in Utah were combined to form plots of UBV data as can be seen in Figure 4. Figures 4a, 4b, and 4c show the eclipse in ten day intervals in the V, B, and U bandpasses. These data are from the HPO and TAO observatories. All of Figure 4 data were selected because they represent a near complete coverage of the eclipse and are in close agreement. Figure 5 shows the R and I data. Campaign Newsletter number 11 contains a complete set of all photometry data through May 1984.

IV. DATA ANALYSIS

A. CEPHEID - LIKE PULSATIONS

Cepheid like pulsations, of the F super giant primary, with a period of 105 to 120 days, have been observed (Guinan 1982). This pulsation complicates the light curve analysis.

B. FLARE ACTIVITY

Variations of 0.06 magnitudes (using a 3940 Angstrom narrow band filter) with periods on the order of minutes have been reported (Xuefu 1984). Figure 6.

C. COLOR CHANGE

Figure 7a and 7b show the B-V and U-B data from just prior to third contact until past fourth contact. Large color changes can be seen around JD 2,445,625 as well as small changes throughout the eclipse.

D. POST INGRESS BRIGHTENING

About 15 days after second contact a brightening of 0.07 magnitudes in the B bandpass and 0.09 magnitudes in the U bandpass can be seen (Figure 4).

EPSILON AURIGAE ECLIPSE DATA

PRIMARY		SECONDARY
	BS 1605	
Mv 3.0 - 3.8		?
SPEC F0 - F2		I ?
DIA 250 X SUN		DIA 2800 X SUN ?
MASS 15 SUNS		MASS 10 - 20 SUNS

DISTANCE 1900 L.Y.

PERIOD 27.1 YEARS

DURATION 2 YEARS

FIGURE 1

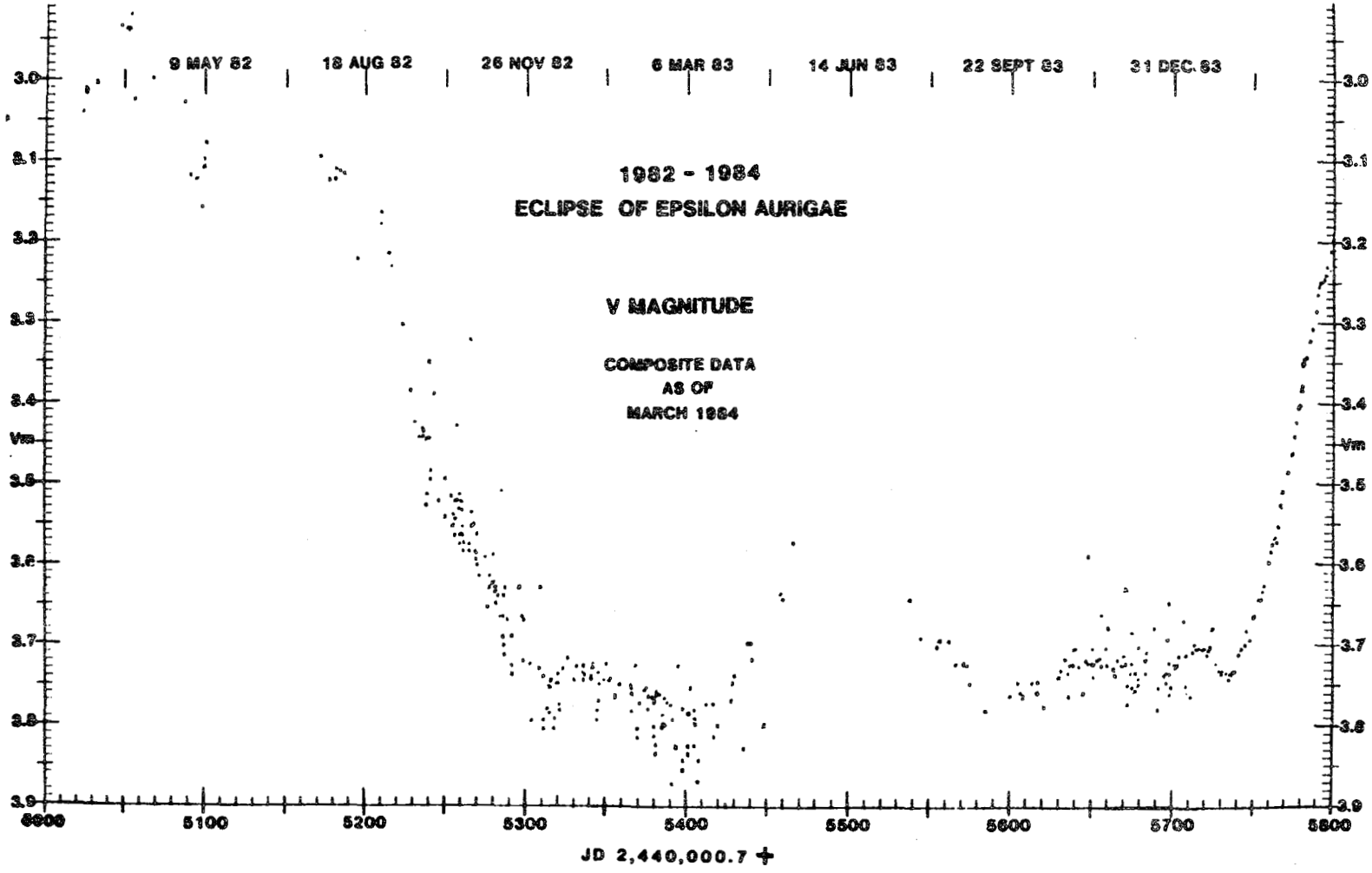
SAMPLE

REPORT DATE 13 MAY 1984
EPSILON AURIGAE COMPOSITE
1982-1984 ECLIPSE

UT	DATE	2440000 + HJD	VISUAL V	N	SD	BLUE B	N	SD	ULTRA VIOLET U	N	SD	NOTES/ OBSERVER	
18	SEPT 80	4501.	3.09	1	----	-----	-	----	-----	-	----	RES IUE	•
4	AUG 81	4821.	3.12	1	----	-----	-	----	-----	-	----	RES IUE	•
29	AUG 81	4846.	3.11	1	----	-----	-	----	-----	-	----	RES IUE	•
	JAN 82												
23	FEB 82	5024.66	3.040	-	.005	-----	-	----	-----	-	----	KK SJC	•
3	MAR 82	5032.70	3.005	-	.009	-----	-	----	-----	-	----	KK SJC	•
9	MAR 82	5048.71	2.932	1	----	-----	-	----	-----	-	----	ECO ML	
22	MAR 82	5051.62	2.937	1	----	-----	-	----	-----	-	----	ECO ML	
23	MAR 82	5052.62	2.938	1	----	-----	-	----	-----	-	----	ECO ML	
25	MAR 82	5054.38	2.920	1	.030	-----	-	----	-----	-	----	RM MO	
26	MAR 82	5057.23	3.025	2	.016	3.508	2	.008	-----	-	----	IED AUO	
4	APR 82	5064.	3.07	1	----	-----	-	----	-----	-	----	RES IUE	•
8	APR 82	5068.29	3.000	1	----	3.529	1	----	-----	-	----	IED AUO	
13	APR 82	5073.	3.15	1	----	-----	-	----	-----	-	----	RES IUE	•
19	APR 82	5079.	3.13	1	----	-----	-	----	-----	-	----	RES IUE	•
25	APR 82	5085.	3.10	1	----	-----	-	----	-----	-	----	RES IUE	•
27	APR 82	5087.46	3.030	2	.040	-----	-	----	-----	-	----	RM MO	
30	APR 82	5091.61	3.120	1	----	-----	-	----	-----	-	----	P/E GCO	
5	MAY 82	5095.43	3.124	4	.020	3.590	4	.030	3.710	4	.040	RM MO	
8	MAY 82	5099.60	3.160	1	----	-----	-	----	-----	-	----	P/E GCO	
9	MAY 82	5100.60	3.110	1	----	-----	-	----	-----	-	----	P/E GCO	
10	MAY 82	5100.42	3.103	3	.030	-----	-	----	-----	-	----	RM MO	
10	MAY 82	5101.58	3.080	1	----	-----	-	----	-----	-	----	P/E GCO	
	JUNE 82												
21	JULY 82	5172.47	3.098	9	----	3.649	3	.005	-----	-	----	SII TAO	
24	JULY 82	5175.	3.26	1	----	-----	-	----	-----	-	----	RES IUE	•
26	JULY 82	5177.50	3.127	6	.003	3.658	3	.014	-----	-	----	SII TAO	
29	JULY 82	5181.50	3.126	4	.009	3.702	3	.012	-----	-	----	SII TAO	
31	JULY 82	5182.49	3.111	4	.005	3.663	3	.008	3.890	3	.005	SII TAO	•
2	AUG 82	5184.48	3.115	3	.007	3.654	3	.017	3.827	3	.014	SII TAO	•
4	AUG 82	5186.50	3.119	3	.009	3.679	3	.011	3.828	3	.011	SII TAO	•
13	AUG 82	5195.61	3.224	3	.015	3.921	3	.020	-----	-	----	RM MO	
14	AUG 82	5196.	3.24	1	----	-----	-	----	-----	-	----	RES IUE	•
24	AUG 82	5206.	3.29	1	----	-----	-	----	-----	-	----	RES IUE	•
26	AUG 82	5210.46	3.180	3	.006	3.737	3	.003	3.891	3	.012	SII TAO	•
28	AUG 82	5210.57	3.168	4	.015	3.849	4	.015	4.001	4	.025	RM MO	
2	SEPT 82	5215.63	3.217	5	.015	3.879	5	.015	4.006	5	.020	RM MO	
4	SEPT 82	5217.48	3.236	3	.007	3.768	3	.009	3.981	3	.009	SII TAO	•
7	SEPT 82	5220.	3.41	1	----	-----	-	----	-----	-	----	RES IUE	•
11	SEPT 82	5224.48	3.305	3	.007	3.884	3	.009	4.059	3	.007	SII TAO	•
16	SEPT 82	5229.41	3.386	3	.015	3.958	3	.009	4.140	3	.012	SII TAO	•
18	SEPT 82	5231.99	3.425	3	.031	3.954	3	.007	4.141	3	.004	JLH HPO	
21	SEPT 82	5234.	3.56	1	----	-----	-	----	-----	-	----	RES IUE	•
21	SEPT 82	5234.98	3.430	3	.005	3.968	3	.003	4.174	3	.005	JLH HPO	
23	SEPT 82	5236.	3.57	1	----	-----	-	----	-----	-	----	RES IUE	•
23	SEPT 82	5236.40	3.442	3	.006	3.973	3	.033	4.163	3	.009	SII TAO	•
23	SEPT 82	5236.98	3.433	3	.005	3.978	3	.003	4.167	3	.008	JLH HPO	
24	SEPT 82	5237.97	3.439	3	.011	3.982	3	.001	4.171	3	.004	JLH HPO	
25	SEPT 82	5238.98	3.446	3	.002	3.977	3	.003	4.174	3	.010	JLH HPO	
26	SEPT 82	5239.--	3.517	1	----	4.098	1	----	4.304	1	----	O/Y JAP	
26	SEPT 82	5239.15	3.529	1	----	4.067	1	----	4.452	1	----	JAPOA	
27	SEPT 82	5240.83	3.350	1	----	-----	-	----	-----	-	----	P/E GCO	
28	SEPT 82	5241.--	3.487	1	----	-----	-	----	-----	-	----	O/Y JAP	

FIGURE 2

FIGURE 3


9 MAY 82
18 AUG 82
26 NOV 82
6 MAR 83
14 JUN 83
22 SEPT 83
31 DEC 83
1982 - 1984
ECLIPSE OF EPSILON AURIGAE
V MAGNITUDE
COMPOSITE DATA
AS OF
MARCH 1984
Vm
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
5000
5100
5200
5300
5400
5500
5600
5700
5800
JD 2,440,000.7 +

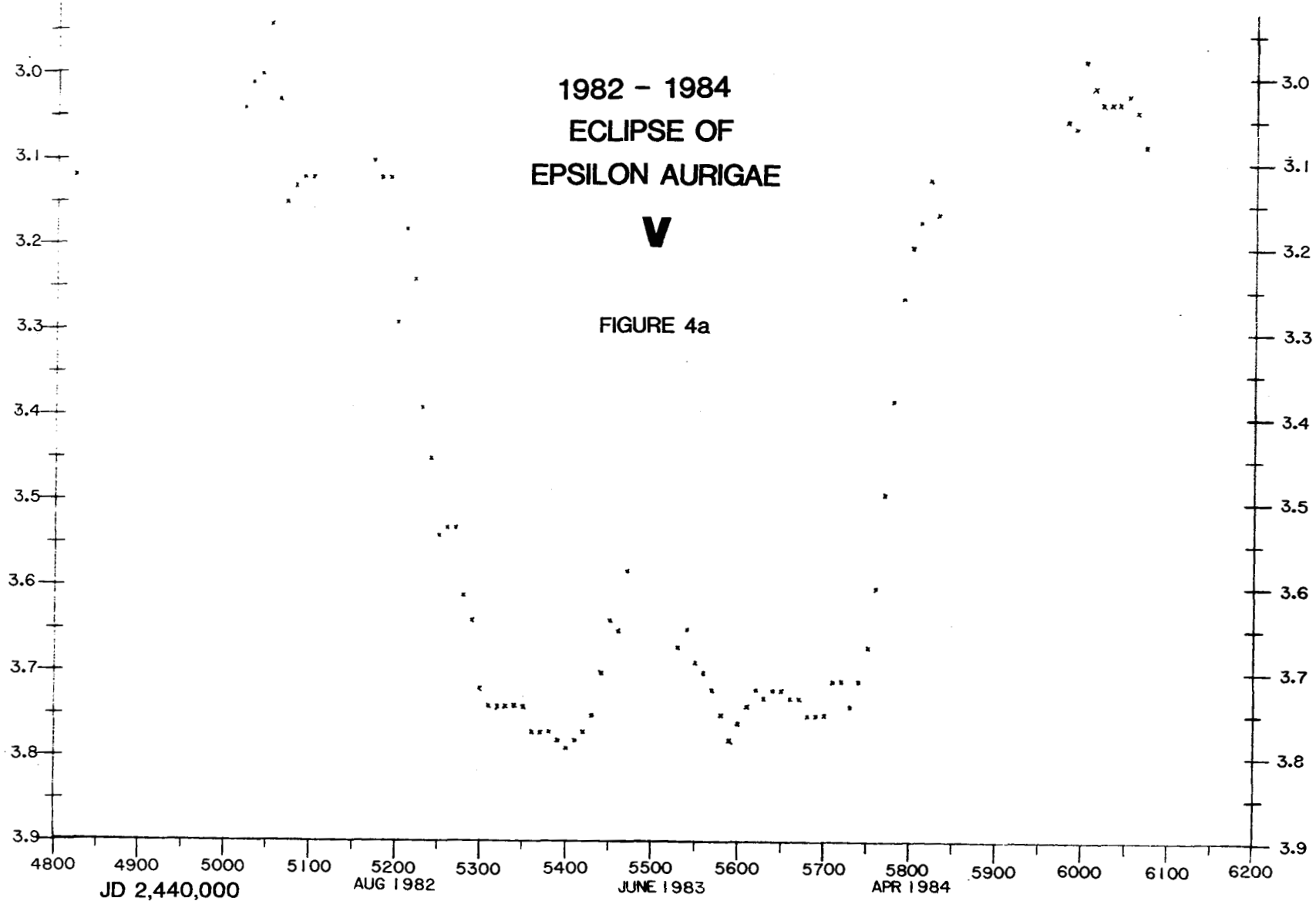

1982 - 1984
ECLIPSE OF
EPSILON AURIGAE
V
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4800
4900
5000
5100
5200
5300
5400
5500
5600
5700
5800
5900
6000
6100
6200
JD 2,440,000
AUG 1982
JUNE 1983
APR 1984

FIGURE 4a

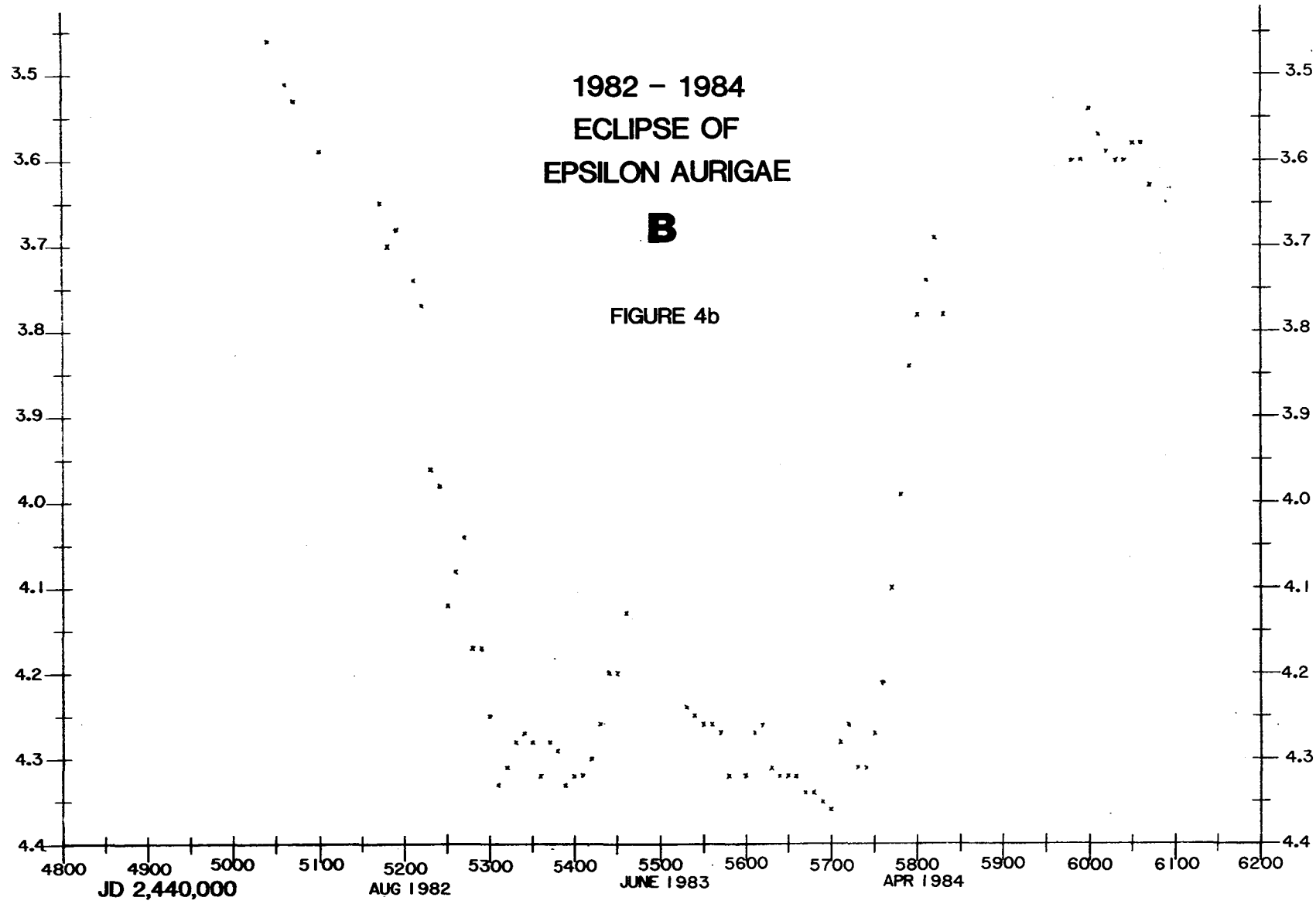
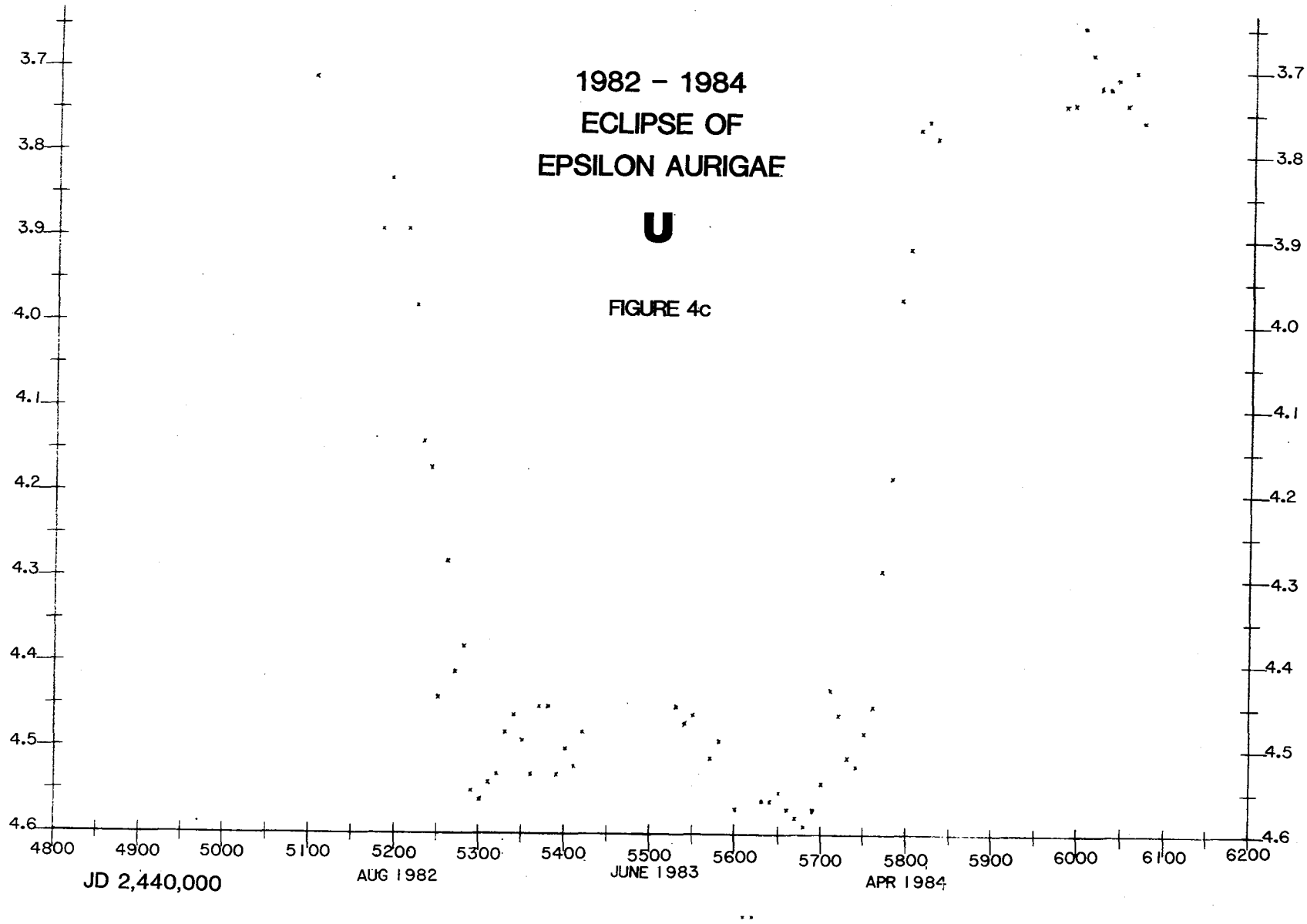

1982 – 1984
ECLIPSE OF
EPSILON AURIGAE
B
3.5
3.6
3.7
3.8
3.9
4.0
4.1
4.2
4.3
4.4
4800
4900
5000
5100
5200
5300
5400
5500
5600
5700
5800
5900
6000
6100
6200
JD 2,440,000
AUG 1982
JUNE 1983
APR 1984

FIGURE 4b


1982 - 1984
ECLIPSE OF
EPSILON AURIGAE
U
FIGURE 4c
3.7
3.8
3.9
4.0
4.1
4.2
4.3
4.4
4.5
4.6
4800
4900
5000
5100
5200
5300
5400
5500
5600
5700
5800
5900
6000
6100
6200
JD 2,440,000
AUG 1982
JUNE 1983
APR 1984

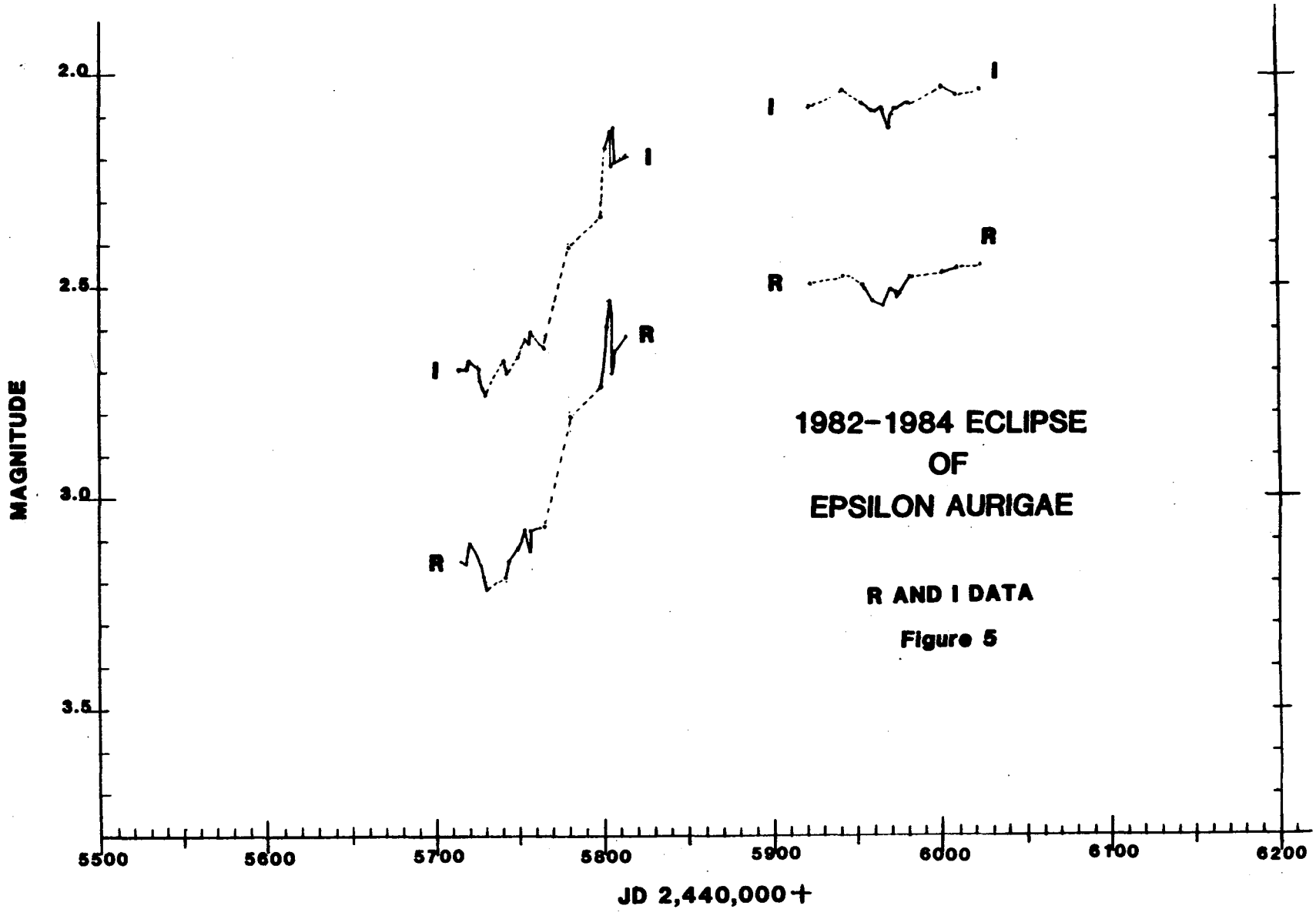

MAGNITUDE
2.0
2.5
3.0
3.5
I
I
I
I
R
R
R
R
1982–1984 ECLIPSE
OF
EPSILON AURIGAE
R AND I DATA
5500
5600
5700
5800
5900
6000
6100
6200
JD 2,440,000+

Figure 5

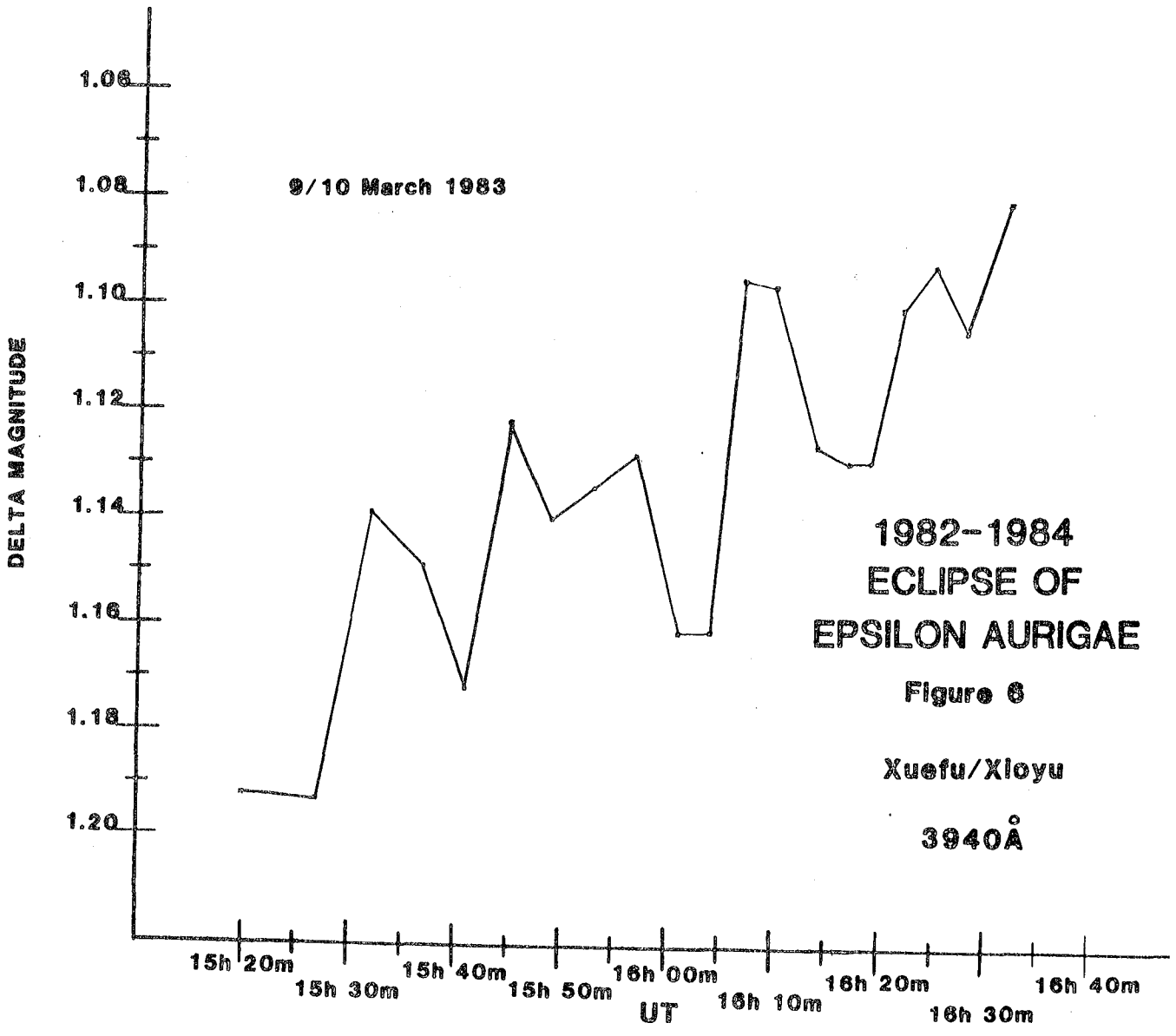

DELTA MAGNITUDE
1.06
1.08
1.10
1.12
1.14
1.16
1.18
1.20
9/10 March 1983
1982-1984
ECLIPSE OF
EPSILON AURIGAE
Figure 6
Xuefu/Xioyu
3940Å
15h 20m
15h 30m
15h 40m
15h 50m
16h 00m
16h 10m
16h 20m
16h 30m
16h 40m
UT

FIGURE 7a

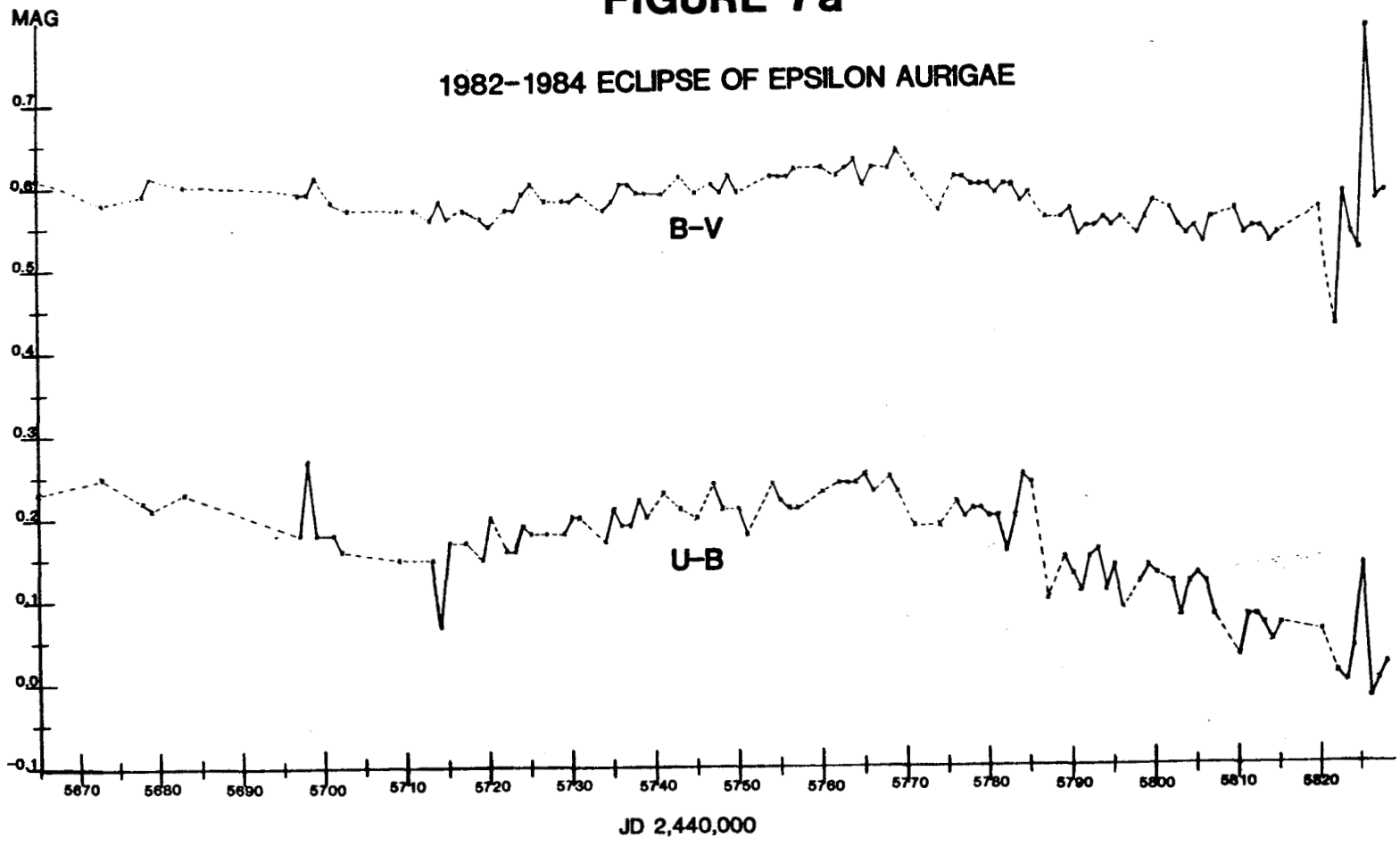
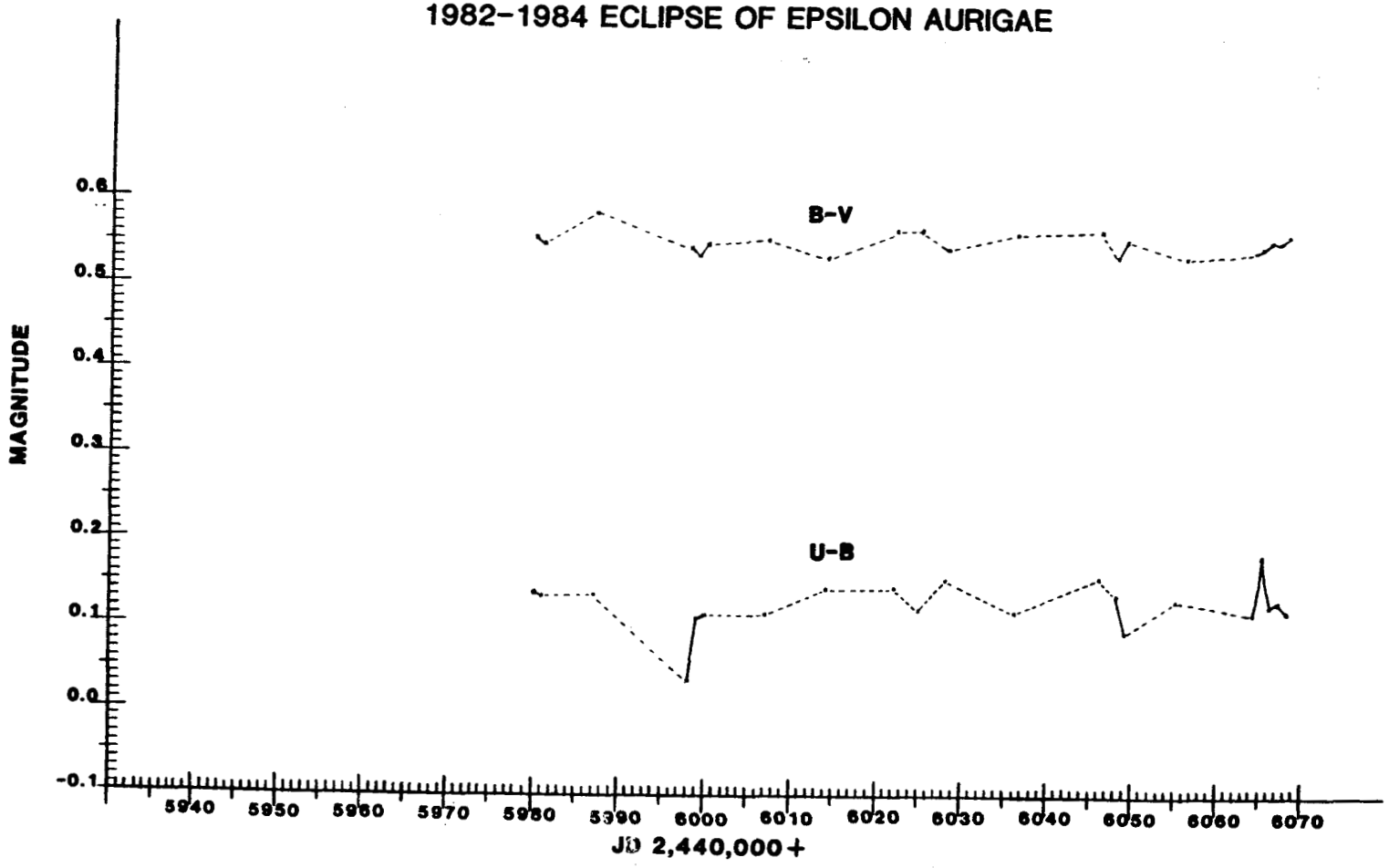

1982–1984 ECLIPSE OF EPSILON AURIGAE
MAG
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
B–V
U–B
5670
5680
5690
5700
5710
5720
5730
5740
5750
5760
5770
5780
5790
5800
5810
5820
JD 2,440,000

FIGURE 7b


1982–1984 ECLIPSE OF EPSILON AURIGAE
B-V
U-B
MAGNITUDE
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
5940
5950
5960
5970
5980
5990
6000
6010
6020
6030
6040
6050
6060
6070
JD 2,440,000+

E. MID-ECLIPSE BRIGHTENING

As seen in the UBV plots (Figure 4) there is a mid-eclipse brightening of over 0.2 magnitudes. A similar brightening was seen in the previous eclipse (Webb 1982). It should be pointed out that all the UBV data for this mid-eclipse brightening have been supplied by the Tjorn Island Astronomical Observatory (TAO) in Sweden. Due to the northern latitude (+58 degrees) of the observatory a near year-around observation of the eclipse was possible. Worst case standard deviation during this period was 0.025 with typically better than 0.01 being obtained. Ferluga and Hack (Ferluga 1984) reported their IUE studies in a paper given at the IUE Symposium. They confirmed the mid-eclipse brightening by observing similar ultraviolet continuum variations. A possible explanation of this brightening has been suggested as due to a gravitational lensing effect (Hopkins 1984). Figure 8 shows a comparison of the 1957 eclipse of VV Cephei and the 1928-1930 plus 1955-1957 eclipses of Epsilon Aurigae. A very noticible mid-eclipse brightening can be seen in the VV Cephei eclipse plus the 1955-1957 eclipse of Epsilon Aurigae. The 1928-1930 eclipse has a sizable gap where the mid-eclipse brightening might be. Other long period eclipsing binaries are being examined for similar brightening.

F. PRE-EGRESS BRIGHTENING

About 40 days prior to egress a brightening (Oki 1984) in all three bands (UBV) is seen (Figure 4). The U band shows a brightening of nearly 0.15 magnitudes, B band 0.07 magnitudes, and V band 0.04 magnitudes.

G. POST EGRESS VARIATIONS

Post egress variations of 0.18 magnitudes in the V bandpass, and 0.23 magnitudes in the B and U bandpasses can be seen (Figure 4). These variations are also seen in the R and I bandpases (Figure 5).

V. CONCLUSION

Although the present eclipse has ended, observations are continuing. Data are need to obtain the light variations of the primary so the variations during the eclipse can be better understood. Perhaps for the next eclipse in 2009 astronomers will have a good model with which to test against new observations.

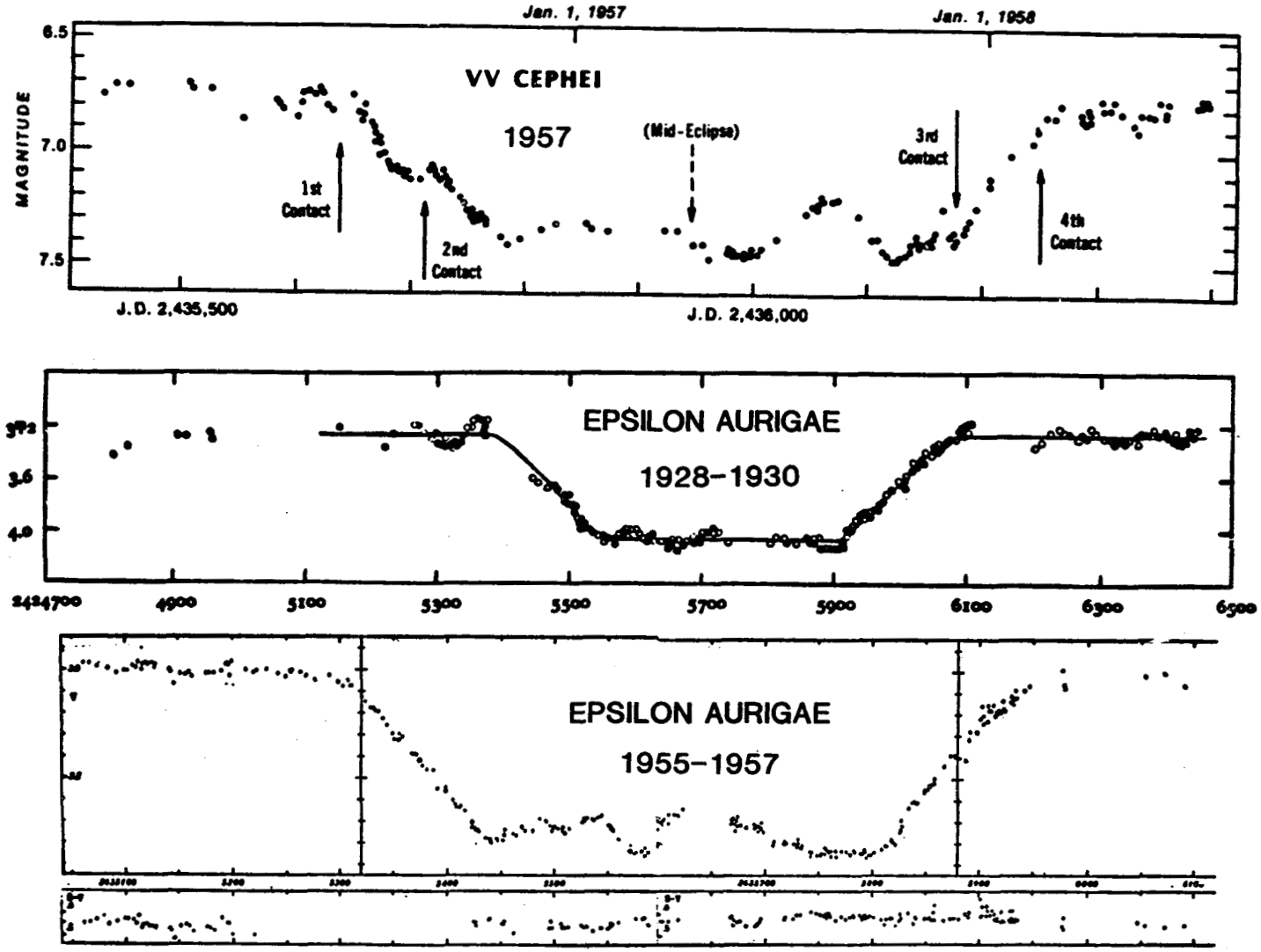

Jan. 1, 1957
Jan. 1, 1958
VV CEPHEI
1957
(Mid-Eclipse)
1st Contact
2nd Contact
3rd Contact
4th Contact
MAGNITUDE
6.5
7.0
7.5
J.D. 2,435,500
J.D. 2,436,000
EPSILON AURIGAE
1928-1930
3.0
3.6
4.0
2434700
4900
5100
5300
5500
5700
5900
6100
6300
6500
EPSILON AURIGAE
1955-1957

FIGURE 8

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