epsilon aurigae

1982·84 ECLIPSE

CAMPAIGN NEWSLETTER

#2

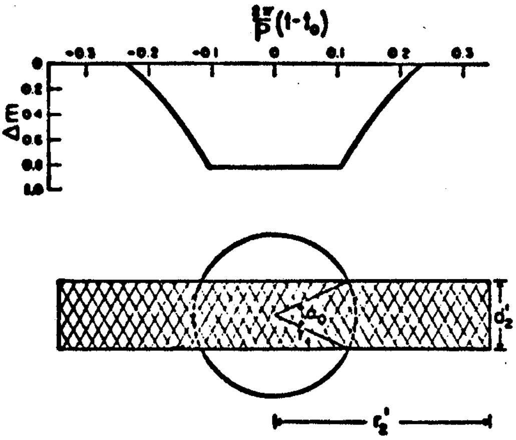

FIG. 1.—A schematic diagram of our model for ε Aurigae and its resulting light-curve during eclipse. It is assumed that we observe this system edge-on. Consequently, the rotating gaseous disk around the secondary component will appear to be a dark rectangle which obscures the primary component during eclipse. The light-curve at the top of the figure is derived by assuming a uniform stellar disk.

Huang 1965 Ap.J. 141

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19.Mar.82

Dear Colleagues:

The response to our first campaign newsletter has been gratifying. At the same time, the observing season is approaching its end for low latitudes. Therefore, it is more urgent than ever that baseline pre-eclipse data be obtained in the coming weeks. At the moment, the spectroscopists appear to be 'ahead' of the photometrists in reported observations, but we expect that to normalize now that the IAPPP has joined in force.

PHOTOELECTRIC PHOTOMETRY

The first photometry report comes from-Guinan, McCook and Donahue (Villanova). Observations made in a narrow band system, using BD+42 117 as comp, showed an 0.1 mag decrease between Dec 81 and Jan 82. However, by Feb 82 the star recovered to the Dec level. As Ed Guinan writes "to the relief of everyone, the eclipse has not begun early. The out of eclipse variations (cf. Gyldenkerne) could arise from changes in the disk geometry or from irregular pulsations of the F supergiant star."

At this writing, eighteen IAPPP members have responded positively to our call for coordinated photometry, primarilly using the UBVRI system. Jeff Hopkins of the Hopkins Phoenix Observatory (7812 W. Clayton Drive, Phoenix AZ 85033) has kindly agreed to co-edit the photometry portion of this newsletter. All reports on observations and suggestions on technique should be sent to Jeff at his address. Our thanks to Jeff for pitching in to help Russ in this much needed way.

Dr. F. B. Wood (U. Florida) is preparing a short article on Eps Aur for our next newsletter. Other news and views are encouraged, along with the much needed photometric data points!

SPECTROSCOPY

Ultraviolet

NASA reviewers have reported been very generous in supporting UV observations of Eps Aur this year. Four separate research teams were approved for fifth year use of the International Ultraviolet Explorer satellite to monitor Eps Aur: Chapman et al. (NASA); Lambert et al. (Texas); Plavec et al. (UCLA) and Simon et al. (Hawaii). In addition, at least one European, M. Hack and company have received observing time from ESA as well.

We hope these groups can agree to co-ordinate their scheduling efforts so as to maximize coverage of the ingress and totality this year. UV observers of Eps Aur may find it useful to be aware of satellite constraints posed by sun angle related heating and cooling, because these can affect lengthy (multi-hour) exposures:

	Interval	Constraint
1982	early May - early Aug	solar occultation zone
	early Sep - mid Oct	excess heating (hot betas)
	late Nov - mid Dec	excess cooling (cold beta)
1983	early Feb - late Mar	excess heating (hot betas)

Chapman (NASA) reports that a far UV low dispersion spectrum obtained 12 Mar 82 required an exposure twice as long as was needed in Aug 81 to reach comparable signal levels. Seemingly, the eclipse has begun at very short wavelengths, due to the high opacity. See also Fig 1a.

Optical

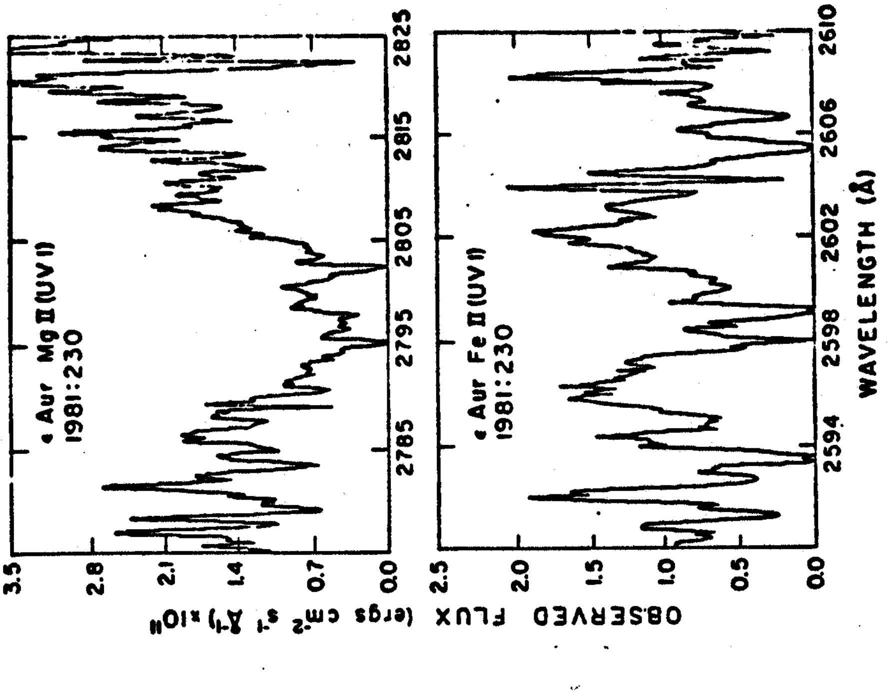
Basri (UCB) has reported a set of spectral scans of the Ca II H-K, Na D, H-alpha and Ca IR triplet obtained at Lick Obs. in Feb.82 (see Fig 1b). Each spectrum actually covers approx. 200A and is available on request.

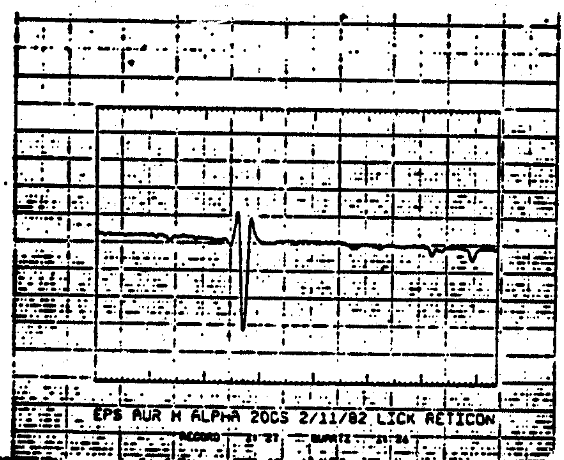
Infrared

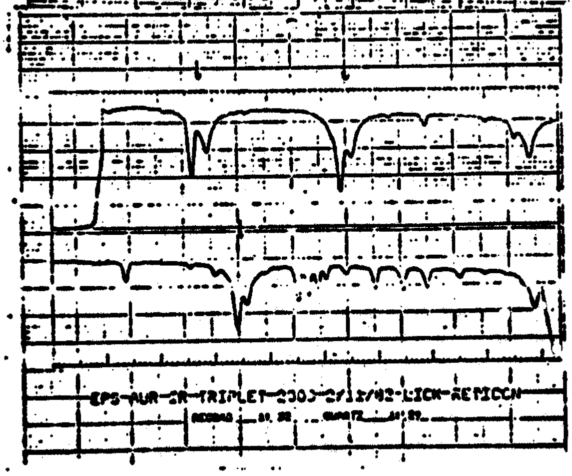
Wallerstein and Suntzeff (U. Wash.) report on an FTS spectrum of Eps Aur in the 2 micron region (R=50,000) which lacks evidence for circumstellar CO features, in Feb.82. George comments that this experiment should be re-done during totality next autumn, and that his recent spectrum also is available on request.

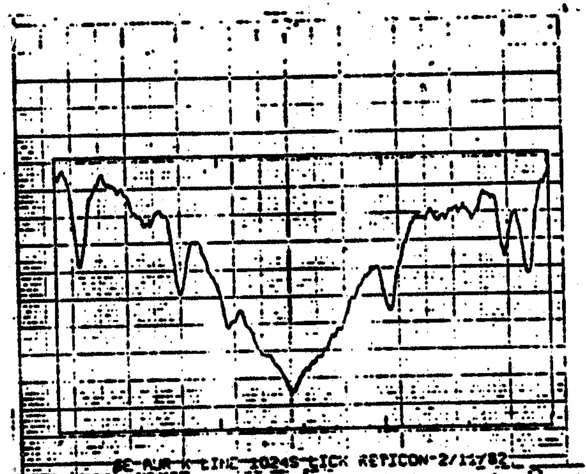
In general, although observations will become increasingly difficult as spring 82 progresses, the chance for pre-eclipse spectra (and photometry) must be exploited so as to maximize comparison with data which can be obtained after July 82, during totality. We will gladly report all interesting observations relayed to us, in an effort to maximize communication.

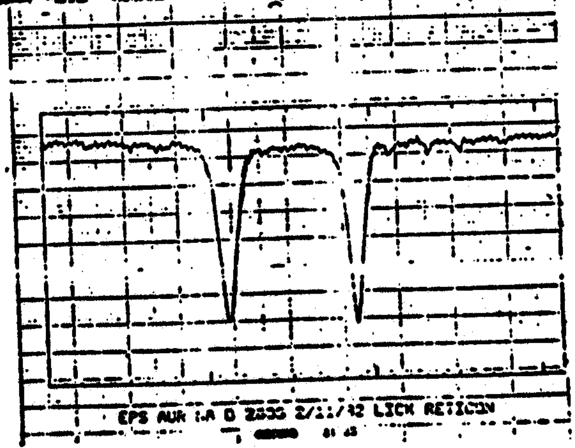
Figure 1 from Chapman, Kondo & Stencel, in Four Years of UV Research, 1982 IUE Symposium (March 30-April 1), NASA Conference Publication (in press).











I.A.P.P.P.C.

International Amateur-Professional Photoelectric Photometry Communication

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November 30, 1981

Dear Jeff:

The I.A.P.P.P. has been asked by several groups to help organize photoelectric photometry of ϵ Aur during its upcoming eclipse, which occurs every 27 years. The situation has been a bit confusing in that Russ Genet got some requests and I got others. The enclosed material, which I have received from one such group, provides some background information and describes how observations might be obtained.

Before deciding to do any photoelectric photometry of ϵ Aur, please be aware of the many serious difficulties inherent in the project:

1. It is very bright, so there might be serious problems with photocell saturation and/or pulse coincidence.
2. The suggested comparison star, λ Aur, is enough fainter that a different major gain step might be required if you use a DC amplifier.
3. Because ϵ Aur and λ Aur are 5° apart and because observations should continue as they get very low in the sky, you must explicitly determine extinction coefficients on every night.
4. Although the difference in B-V between ϵ Aur and λ Aur is fairly small, you must know your transformation coefficient

I am led to believe that Dr. Miroslav Plavec (Astronomy Department, U.C.L.A.) will be the coordinator who will receive and coordinate any observations which you (and professional astronomers) obtain. Because his role in this needs to be confirmed, however, I'll let you know later exactly where to send your data.

Sincerely,

Douglas S. Hall

Douglas S. Hall

PROPOSAL FOR EXTENDED OBSERVATIONS OF EPSILON AURIGAE

I. Introduction

The eclipsing binary star ε Aurigae will begin its next eclipse in July, 1982. We would like to bring the need for observations of this star, extending over at least the next four winters, to the attention of the telescope scheduling committee and the IFA staff. We plan to submit proposals in each of those seasons, and we hope that this advance notice will aid scheduling and help us receive the necessary telescope time. The eclipse occurs only once every 27 years, so this opportunity should not be missed.

The main questions about this system are:

(1) What is the nature of the material which produces the extinction during the eclipse?

(2) What is the nature of the secondary object associated with the eclipse?

(3) What is the cause of the small irregular brightness and color variations which occur at all orbital phases but which increase in magnitude during the eclipse?

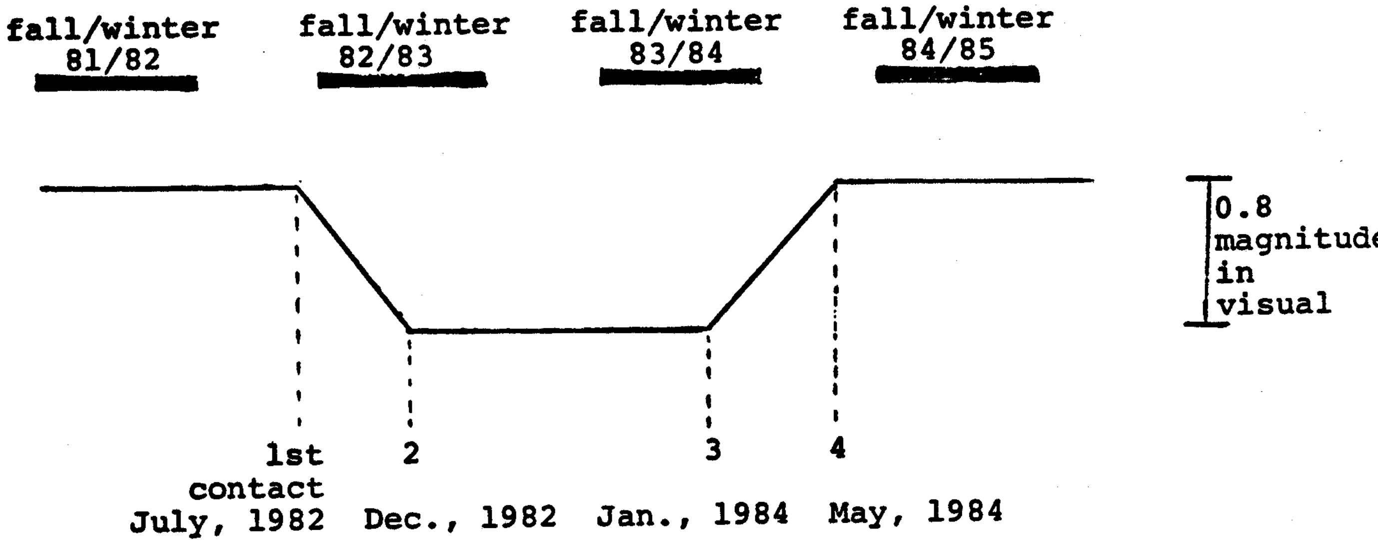
The known properties of the system are summarized in a later section.

The competing models are:

(1) The secondary is a hot star which has ionized a large, optically thin disk of gas, somewhat inclined to the line of sight. In this model, the extinction is due to Thomson scattering in the disk of plasma and the primary is completely behind the disk during mid-eclipse[1,2,3,4].

(2) The secondary is in the midst of a disk of solid particles with the extinction provided by geometric screening[5,7,8]. Two extreme subcases are (a) a disk inclined to the line of sight which has $\tau = 50\%$ and which completely covers the primary[6,9,12], and (b) an opaque disk lying in the line of sight which covers 50% of the primary at mid-eclipse[10,11,12].

Note that model (2) may not involve a central condensation at the secondary's position--the mass of the disk alone might equal the $\gtrsim 15 M_\odot$ expected (see below). These models are also interesting considering that the primary's luminosity and proximity to the Aur OB1 association imply an age of $<10^7$ years[13]. The possibility is suggested that we are observing a planetary system in formation[6].



Epsilon Aurigae = B.S. 1605 $m_v = +3.0 - +3.8$

$\alpha_{1950} = 4^h\ 58^m$
$\delta_{1950} = +43° \ 45'$
$b_{II} \sim 2°$

Bars indicate periods of practical viewing from Mauna Kea.

II. Observations

The following observations need to be made:

(1) Determination of the extinction during the eclipse across as broad a range of wavelengths as possible.

(2) Search for any thermal continuum above that expected from the F0 primary which can be attributed to the secondary, at both UV and IR wavelengths. This search will be made easier by the eclipse, which will cut the primary's brightness down by a factor of ∿2.

(3) Search for absorption lines in the UV and IR produced by the eclipsing material.

(4) Correlation of the minor variations in (V) and (B-V) which are superposed on the main, trapezoidal light curve with variations at other wavelengths, and with velocity variations in the primary's spectrum.

The characteristic time scale of the small, irregular light variations is very roughly 100 days[14,15,16]. These variations need to be studied in and of themselves, but more importantly, they must be tracked to allow any study of the main, mean light curve. Thus, observations need to be made at least every 50 days during the period when ε Aurigae can be practically observed form Mauna Kea (∿7 months each year, centered on December 10) for the next 4 winters, including the present one (81/82).

We have JHKLM photometry from the last two winters to aid in the determination of a baseline. Dr. Douglas Hall of Vanderbilt University has agreed to be our liason to a network of amateur astronomers with photometric equipment. They will provide regular monitoring (∿several nights per week) of the visual brightness and colors of ε Aurigae, to which our more widely-spaced observations can be referred.

We propose to take responsibility for the 1-5 μm broadband, 1-3 μm CVF, and 10 μm broadband measurements. The primary star reaches a minimum brightness of $M_V = +3.8$, so these observations can be done quickly and can easily share nights with other programs. We hope to request help from the following people to complement our measurements:

IFA Staff	Visual Spectroscopy
Cruikshank, Howell	3-5 μm CVF
IRTF Staff, visitors	10 μm CVF, 10 and 20 μm photometry
H.I.G. - P.G.S. Staff	Visual medium-band photometry

Our own schedule for winter 81/82 follows:

Dec. 7-9, 1981	88"		10μm, JHKLM photometry
Dec. 10-13, 1981	88"		1-3μm CVF, shared with Gaffey
Jan., 1982 (2 nights)	88"	to be proposed	10μm, JHKLM photometry
Feb., 1982 (2 nights)	88"		
1st quarter, 1982	24"	to be proposed	JHKLM photometry, 1-3μm CVF

Ted Simon has requested IUE time for next spring, and has access to IUE observations of ε Aurigae made during the last year. He is also proposing daytime IR Fourier Transform Spectrometer observations at the Kitt Peak 4-meter telescope during ingress next summer.

We suggest the following comparison stars:

Visual, near-IR Broadband photometry	λ Aurigae (B.S. 1729) $m_V = +4.7$ spec = G0 (distance from ε = 5°)
Far-UV, 10- and 20-μm photometry	α Aurigae (B.S. 1708) $m_V = +0.1$ spec = G8 (distance from ε = 3 1/2°)
Visual, IR spectrophotometry	β Tauri (B.S. 1791) $m_V = +1.6$ spec = B7 (distance from ε = 16°)

The nearest two stars of roughly the same spectral type as ε Aurigae which appear in the Bright Star Catalog and which do not appear to be variables or spectroscopic binaries are:

	m_V	spec	α (1950)	δ
B.S. 825	+6.3	A5Ia	$2^h45.^m8$	+56°53'
B.S. 2066	+6.4	A2Ib	5 53. 4	+28 56

III. Summary of the known prop~~o~~erties of ε Aurigae

(1) The primary has a spectral type of F0Ia. Its mass is estimated to lie in the range 15-40 M⊙.

(2) From spectroscopy and astrometry: the primary's orbit has a radius of $a_1 \sin i = 13$ A.U. (18); the inclination $i \geq 70°$ (17); the distance of the system is ∿1 kpc, so the primary has an $M_V = -7$ without taking extinction into account (17); the mass function

$$f = \frac{m_2^3 \sin^3 i}{(m_2 + m_1)^2} = 3.1 \text{ M}_\odot$$ (18). Combined with the

the range for the primary's mass, this gives a mass range for the secondary of 15-25 M⊙.

(3) No secondary spectrum is observed at any orbital phase, and no secondary eclipse is seen.

(4) The eclipse light curve is trapezoidal with a depth of 0.8 magnitudes at visual wavelengths. Ignoring the small, irregular variations (see (5) below), the "bottom" of the eclipse is close to flat and lasts ∿390 days, while the ingress and egress phases each last ∿140 days.(14)

(5) There are small, irregular variations on time scales of ∿ 100 days in (V) and (B-V) which occur at <u>all</u> orbital phases (14, 15, 16). Δ(V) is ∿0.1 magnitudes outside of the eclipse and increases to 0.2-0.3 magnitudes during the eclipse. The relation between Δ(V) and Δ(B-V), extracted by assuming that the eclipse is a perfect trapezoid, is linear(14). There are also small, irregular velocity variations in the F star's spectrum at all orbtial phases of amplitude ∿8 km/sec(18) which may or may not be related to the light variations.(14,19)

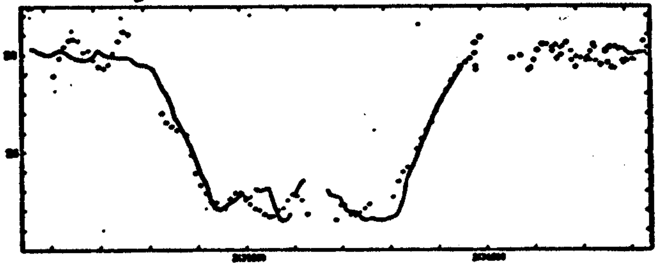


FIG. 4. The 1928–30 light-curve (plus-signs, upper abscissa scale) superposed upon the 1955–57 light-curve (smooth curve, dots in post-eclipse phases; lower abscissa scale). The ordinate scale represents 1ᵐ for the 1955–57 eclipse.

FIG. 2. The deviations Δ(B–V) from the mean colour index plotted against the deviations ΔV from the mean magnitude for totality. The open circles correspond to the phases at the second contact, the plus-signs to the phases at the third contact.

from (14)

(6) There is at most a change in (B-V) of +0.02 magnitudes from pre-eclipse to full eclipse, again ignoring the small, irregular variations.(14) Thus, in the range of wavelengths available during previous eclipses, the extinction is close to "grey".

(7) No absorption lines other than those belonging to an F0 star are observed during the eclipse at visual wavelengths. (1, 19, 20, 21 and refs. therein.)

(8) Many of the F0 star's absorption lines show a systematic velocity shift, as the eclipse progresses, of about 50 km/sec. These line start with a slight red-shift up to several years prior to the eclipse, tend to be unshifted but stronger than outside eclipse at mid-eclipse, and end the eclipse blue-shifted. Lines which show this behavior generally have metastable or ground states for their lower levels.

Perhaps the most important point of all is that (3) and (4) together are definitely <u>inconsistent with an eclispe by an opaque spherical body</u>; (2) implies that the system is well separated, so that rapid mass-transfer is not taking place; (2) and (4) together imply that the eclipsing matter extends <u>at least</u> 9 A.U. along its orbit.

The temperature of solid matter at the position of the secondary solely due to illumination by the primary will be ∿1000°K.(18) The Poynting-Robertson effect will suffice to de-orbit any body smaller than ∿10 cm orbiting the secondary in ∿10^5 years, which provides a lower limit on the size of any solid particles in the system.

Item (8) implies that the gas responsible for the extra absorption during the eclipse is excited by the primary but is quite distant from it. The velocity shift has a size and sense consistent with direct orbital motion about the secondary, given the secondary's mass and the size of the obscuring disk.

Finally, the simple separability of the small light variations from the eclipse suggest that they are not part of the obscuring phenomenon. The fact that these variations increase from 0.1 mag to about 0.2 mag while the primary's light is cut by 50% suggests they are flickerings of constant energy ocurring in a region not obscured by the secondary.

Dana Backman
Jeff Bell

Planetary Geosciences/HIG

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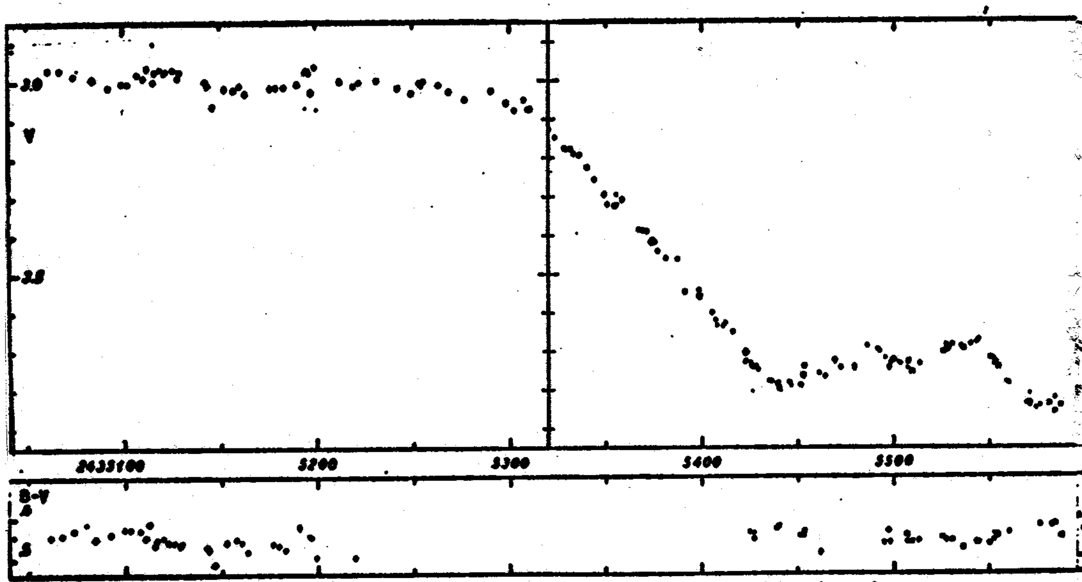

FIG. 1a. The V and B–V light-curves of ε Aurigae during the pre-eclipse phases, the ingress-phase and the first part of the totality. Dots: Sophienholm Station; crosses: Stockholm Observatory; plus-signs: Flower and Cook Observatory; open circles: Hamburg Observatory.

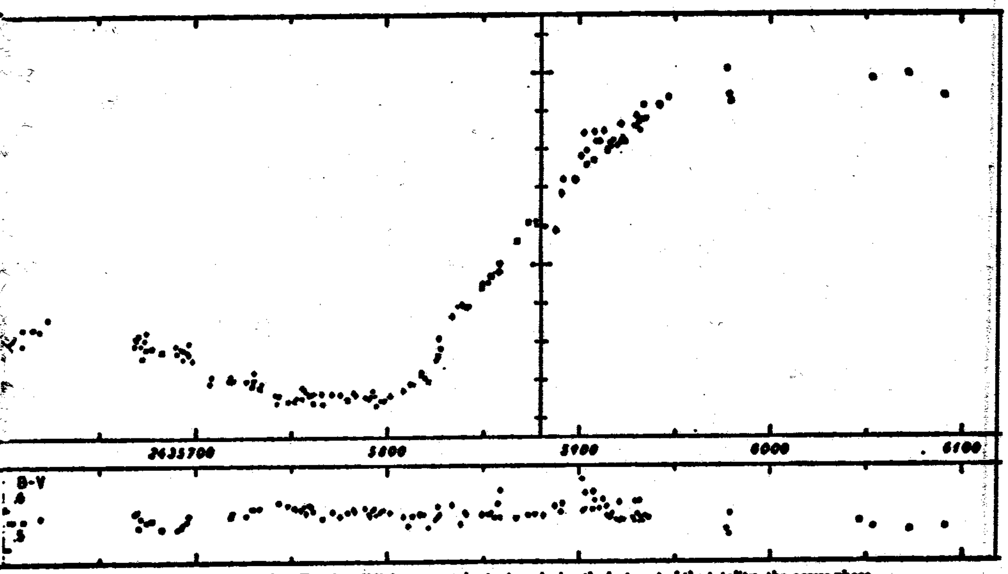

FIG. 1b. The V and B–V light-curves of ε Aurigae during the last part of the totality, the egress-phase and the post-eclipse phases. Dots: Sophienholm Station; crosses: Stockholm Observatory; plus-signs: Flower and Cook Observatory; open circles: Hamburg Observatory.

Gyldenkerne (1970)