# epsilon aurigae

## 1982·84 ECLIPSE

## CAMPAIGN NEWSLETTER #3

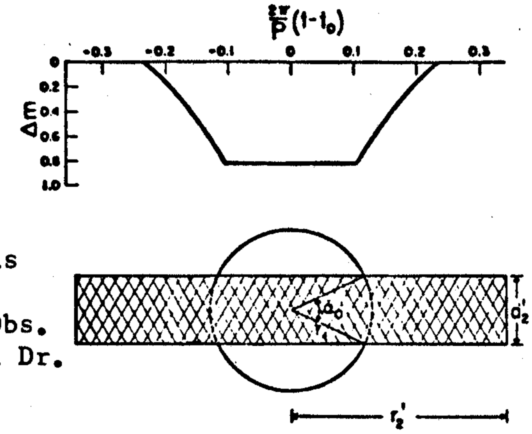


FIG. 1.—A schematic diagram of our model for ε Aurigae and its resulting light-curve during eclipse. It is assumed that we observe this system edge-on. Consequently, the rotating gaseous disk around the secondary component will appear to be a dark rectangle which obscures the primary component during 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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30.Jun.82

Dear Colleagues;

The newsletter staff has undergone some re-organizing and some relocation since our last report. Hence the time delay between second and third reports. The photometry from the observing season just ended has been trickling in, and we are pleased to present the light curve for Epsilon Aur through June. We wish our Nordic observers success in their efforts to follow the star through its lower culmination. The next big observing season is coming soon. The ultraviolet satellite will get its first look past the solar constraint in late July. Recall that first contact is predicted for 29 July.

The Epsilon Aur article in the May issue of Sky & Telescope by Francis Reddy was inspirational. We are pleased to append to this newsletter a compilation by James Webb which also examines the mystery surrounding the system. There has also been some discussion about an international colloqium on the subject of Epsilon Aur and related stars to be held in the US or Canada sometime following the eclipse in 1985. This would provide an outstanding format for presentation of all photometric and spectroscopic efforts on this eclipse.


We wish to acknowledge the support of the American Astronomical Society and NASA in production of this third newsletter. Unfortunately, there is no free lunch in astrophysics either, and we append a subscription request to support future newsletters.


## PHOTOELECTRIC PHOTOMETRY

Once again, Ed Guinan and colleagues at Villanova U. have furnished us with the most complete photometry to date. Note that the light curve (Figure 1) is obtained on their own particular narrow band system, using BD+42°1170 as comparison. This latter star is much fainter than Epsilon Aur and requires a well calibrated/stabilized amplifier to use successfully. Other PEP workers may wish to continue using Lambda Aur as the comparison as well (see below). The fluctuation in Guinan's light curve do not represent ingress of the 0.8 mag eclipse, but are judged to be Cepheid-like pulsations of the F supergiant star, on a 105-120 day timescale. The ultraviolet observations clearly show continuum fluctuations as well. Comments in Newsletter #2 regarding UV changes can now be put in their proper context, as Cepheid-like changes.

PEP census forms are attached, as well as additional observing suggestions. Please fill out the form and remit to Jeff Hopkins as indicated. This systematized inventory will help in pulling together the final light curves. Russ Genet remains active in our campaign, but is feeling overloaded with other IAPPP activities.

The response to our campaign request at the recent IAPPP symposium at Big Bear has been wonderful. Several new inspired PEP workers have signed on, and they have our encouragement!

Epsilon Aur is not the only long period eclipsing system undergoing eclipse this year. A related system called 31 Cygni will be going through its 10 year eclipse season this autumn and is very favourably placed for evening observations. Potential comp stars include 30 Cyg and Rho Cyg, but these may be updated in the next newsletter. The ingress on this 3784 day binary last only TWO DAYS. It is predicted for Sept. 3-10, 1982. Totality lasts 60 days (mid eclipse approx. Oct. 11), and the rapid egress will occur during the week of Nov 13. The light curve on this object will help to place the spectroscopy in proper context with respect to the eclipse. Any data you might obtain should be clearly labeled as 31 Cygni data and forwarded to Jeff Hopkins.

## SPECTROSCOPY

Several sets of pre-eclipse spectra (high resolution) were obtained in March & April 1982 in both the optical and UV spectral regions. The UV data clearly shows a wavelength dependent continuum fluctuation correlated with the optical light curve fluctuations (discussed above). UV and IR observations will resume in earnest in late July as the eclipse begins. A schedule of the proposed dates of observation with the UV satellite is appended.

News from spectroscopists:

M. Saito and colleagues at the University of Kyoto will be using their 1.9 meter telescope at Okayama for spectroscopy (3400-8000A) and IR photometry.

J. Rahe and colleagues at Dr.-Remeis Obs.-Bamberg will obtain optical spectra at their Carlo Alto Obs. this autumn in support of the campaign.

D. Strickland (Royal Greenwich Obs.) and K. Rao (India) are collecting optical high dispersion spectra and scanner data in addition to their part in the European UV observations.

We solicit short communications from all spectroscopists indicating their plans and any preliminary results. One of the purposes of this newsletter is to aid the communication between observers so that efficiant telescope use and collaborations can occur.

Proposed IUE schedule for Epsilon Aurigae: Summer/Fall 82, preliminary

| | |
|---|---|
| July 24, 29 | Goddard, USA |
| Aug. 9 | " |
| Aug. 24 | " |
| Aug. 30 | " |
| Sept. | Vilspa, Spain |
| Sept. 5 | Goddard |
| Sept. 20 | " |
| Oct. 9 | " |
| Oct. 11 | " |
| Oct. 25 | " |
| Nov. | Vilspa |
| Nov. 1, 8, 22 | Goddard |
| Dec. 6, 13, 20 | Goddard |

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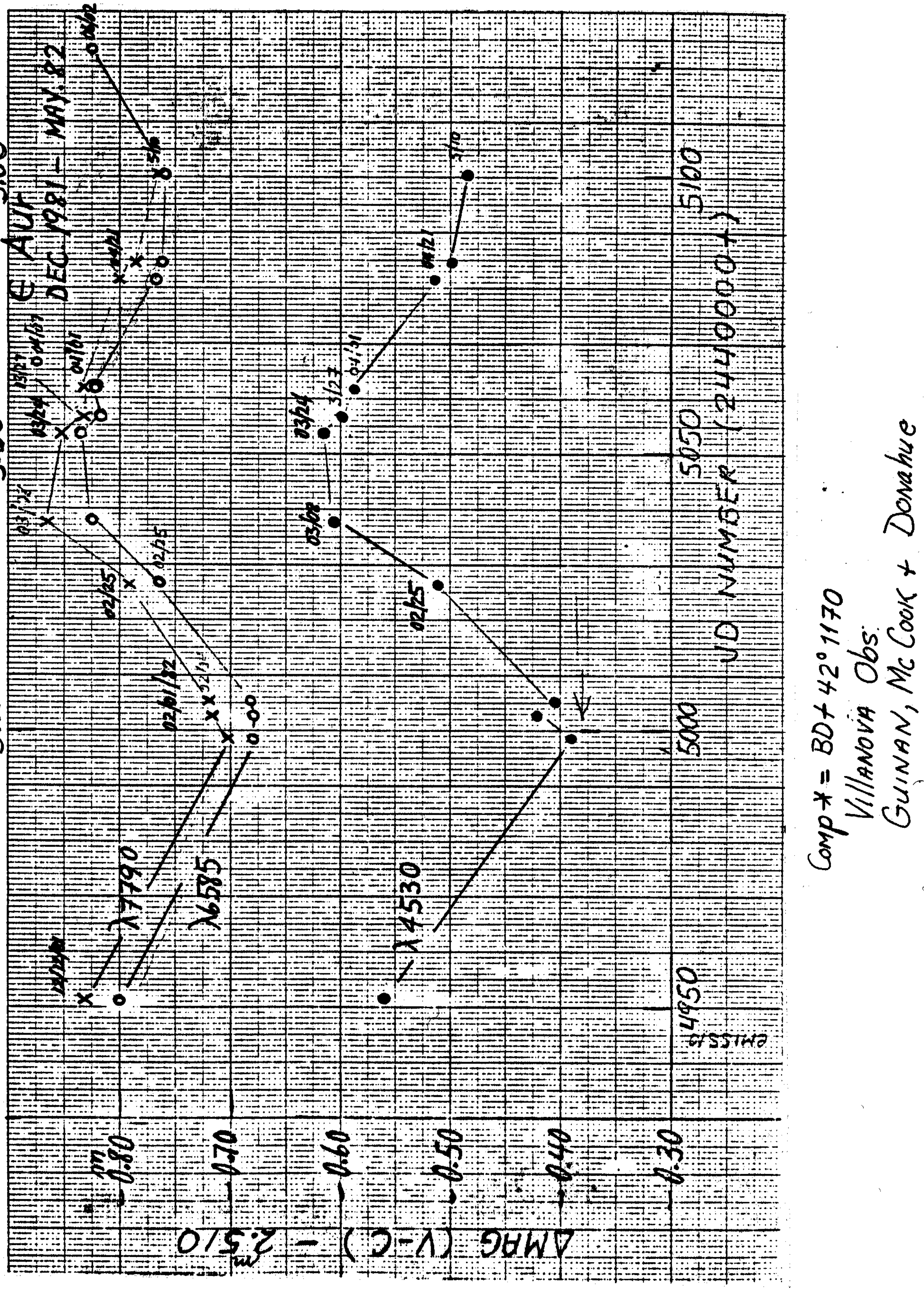
In a brief note from D. McCrary, it is proposed that an accretion disk with a high spin rate might reveal itself in red-shifted line components during the ingress phase of the eclipse. Any systematic flow will be revealed by doppler shifted components in spectral lines formed in such flows, and these may be important clues.


ε Aur
DEC. 1981 – MAY 82
JD NUMBER (2440000+)
ΔMAG (V-C) – 2.510
λ7790
λ6585
λ4530
Comp* = BD+42° 1170
Villanova Obs.
Guinan, McCook + Donahue

On July 29 of 1982 an important and rare eclipse of the Epsilon Aurigae system is predicted to occur (Gyldenkerne 1970). The nature of this system remains unclear at the present time. The upcoming eclipse provides a chance to observe this system simultaneously in many frequency bands. Observations of this type will undoubtably be useful in selecting the correct model for this system.

The Epsilon Aurigae system appears to contain a third magnitude primary in a binary configuration with an object whose nature is unknown. The light curve of the system reveals its binary nature and has a roughly flat minimum. Spectroscopically it appears as a single lined binary with a period of 27.1 years which agrees well with the period of the light variation. The expected secondary minimum has not been detected. Another baffling characteristic of the light curve is the difference in the shape of the minima from one eclipse to another. Spectral analysis of the system indicates that only the F2 I supergiant can be seen, even during primary minimum. The loss of light during the primary minimum occurs at all frequencies simultaneously, suggesting an eclipse phenomena. The primary complicates matters even further by being a pulsating variable with cyclic but not periodic variations of up to .2 magnitudes.

All of these characteristics provide a challenge to the theoretician who attempts to model this system. Many models have been proposed with limited success. These models range from black holes to a pre-stellar nebula as the eclipsing secondary component. Observations obtained during the forthcoming eclipse may well provide the necessary clues as to the nature of this system.

## The History of Epsilon Aurigae

The nature of Epsilon Aurigae was discovered in 1821 by Fritsch (1824). The next reported observations were made visually by Schmidt, Heis and Argelander during the 1848 eclipse (Gussow 1936). Vogel and Eberhard (1902) confirmed the eclipsing nature of the system by radial velocity measurements. Ludendorff (1904) determined its period to be 27.1 years with a flat bottomed eclipse which lasted about two years. Since the 1902 eclipse, the Epsilon Aurigae system has received much attention by observers.

The 1928-1930 eclipse was watched closely by Huffer (1932) and Gussow (1936) and others. Huffer obtained data on 98 nights between January of 1928 and May of 1931. He observed the eclipse in April of 1928 which lasted until May of 1930. The expected .8 magnitude decrease in light was observed along with approximately .2 magnitude non-periodic fluctuations. Huffer also pointed out that a secondary minimum was predicted by Ludendorff which was to occur in 1947. The decrease of light, however, might only be about .06 magnitudes which would be difficult to seperate from the .2 magnitude aperiodic variability of the primary. This minimum was not detected.

The next primary minimum, again as calculated by

Ludendorff, was expected in 1955. In preparation for the 1955-1957 eclipse, F. B. Wood (1958) organized spectrographic and photometric observers to get a complete set of observational data of the Epsilon Aurigae system. Publications listed in Gyldenkerne (1970) and the observations present there are the results of that campaign. Many observations of the system out of eclipse have been made. Some of these references are listed in table 1.

Table 1

| | |
|---|---|
| spectrum | Hack (1959) |
| | Hill et al. (1975) |
| infrared observations | Low and Mitchell (1975) |
| ultraviolet observations | Hack and Selvelli (1979) |
| astrometry | Strand (1959) |
| | Van De Kamp (1978) |
| radial velocities | Wright (1970) |

The orbital elements were first derived by Ludendorff (1904) and later revised by Wright (1970). The orbital elements due to Wright are taken from Sahade and Wood (1978) and listed in table 2.

## Table 2

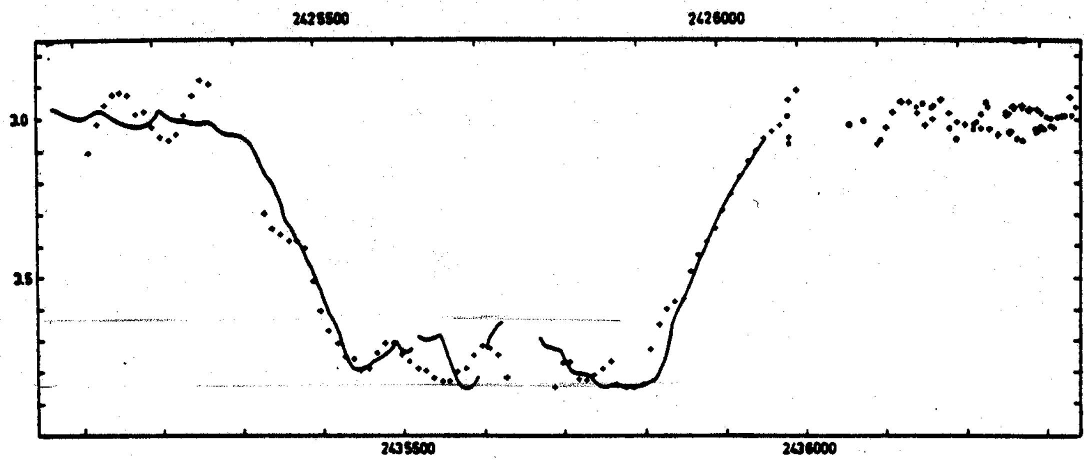
| | |
|---|---|
| Half range of radial velocity | 15.0 Km/sec |
| radial velocity of center of mass | -1.4 Km/sec |
| eccentricity | 0.20 |
| semi-major axis asin i | 2E9 Km |
| mass function f(M) | 3.12 solar masses |

The period adopted by Gyldenkerne (1970) is about 9885 days. Table three contains his predictions for the forthcoming eclipse.

## Table 3

| | |
|---|---|
| 1st Contact | July 29. 1982 |
| 2nd Contact | December 11, 1982 |
| 3rd Contact | January 09, 1984 |
| 4th Contact | May 29, 1984 |

The light curves for the 1928 and 1958 eclipses are reproduced below and are taken from Sahade and Wood (1978) and are originally due to Gyldenkerne (1970).




The light curve of Epsilon Aurigae at minimum is illustrated by Gyldenkerne (1970). Smooth curve and dots, lower absicissa scale: 1955-1957 eclipse; plus signs, upper abscissa scale: 1928-1930 eclipse.

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Apart from the differences in the morphology of the light curves, notably the "hump" in the bottom of the 1958 light curve, the durations of the various phases of minimum are compared in table 4. The data presented here is from Huffer (1932) and Gyldenkerne (1971) for the 1928 and the 1958 eclipses respectively.

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Table 4

| | | ........... delta | t ........ | | |
|---|---|---|---|---|---|
| | loss of | 1st-2nd | | 3rd-4th | T |
| date | light | contact | minimum | contact | total |
| 1928 | 0.81 mags. | 197 days | 360 days | 197 days | 754 days |
| 1958 | 0.71 mags | 135 days | 394 days | 141 days | 670 days |

## Models of Epsilon Aurigae

Physical models for the Epsilon Aurigae system have evolved from the first suggestion that the secondary component is an enormous infrared star eclipsing the F supergiant to a collapsed object surrounded by a thin ring of accreting matter. At the present time there is no generally accepted model, but some of the leading candidates show promise in explaining this mysterious system.

Kuiper, Struve, and Stromgren (1937) proposed the existence of a low density infrared star in a binary configuration with the visible F2 I supergiant. Electron scattering provided the attenuation of light to cause the primary. Infrared observations by Low and Mitchell (1975) showed no infrared excess that this model predicts. In 1959, Hack (1959) proposed another type of model for this system. Her model consisted of a small secondary component surrounded by a large gaseous envelope which contains large particles that scatter light from the primary. Huang (1965) suggested the flat bottomed eclipse could be caused by a retangular shaped secondary component, actually an opaque thick disk surrounding a small star viewed edge-on, eclipsing the primary. This model received criticism from Wilson (1971) for two reasons. The first is the stability of the "thick" disk is suspect and the second is that this model requires the primary to be one of the most luminous stars in the galaxy. Van de Kamp (1978) determined the parallax of Epsilon Aurigae using astrometric and spectroscopic measurements and concluded that the F star is not nearly as luminous as Huangs' model predicts. Kopal (1971) and Cameron (1971) proposed models based on a collapsed object surrounded by a semi-transparent disk inclined about 90 degrees to the orbital plane. Wilson (1971) proposed a thin opaque disk of dust surrounding a collapsed object. Both the Cameron and Wilson models incorporate a black hole in the center of these disks. Wilson, however, assumes the disk is oriented nearly in the orbital plane and has a central opening which is semi-transparent. The ring of dust eclipses the primary and the transparency of the central opening, or changes in it, can explain the differences between the 1928 and 1958 light curves. Handbury and Williams (1976) propose a secondary composed of a pre-stellar cloud that eclipses the primary. They suggest that if this is a pre-stellar nebula in the Epsilon Aurigae system we might possibly see it as it begins its stellar life. Hack and Selvelli (1979) observed Epsilon Aurigae in the ultraviolet and detected a larger flux at wavelengths less than 1650. They classify the primary as a F0 Ia star with absolute visual magnitude of -7. They conclude that the secondary might be a late B dwarf on the main sequence with a ring of gas surrounding it. This gas ring is a result of a nova explosion of the B dwarf. They also suggest the secondary could be a Be star surrounded by a 1E-6 solar mass ring.

Although some of these models adaquately explain some facets of this unusual binary system, observations of the coming eclipse will be important in selecting the correct model. Observations in the ultraviolet and x-ray frequency bands are encouraged as well as photometry and spectroscopy.

James R. Webb

## REFERENCES


Cameron (1971) Nature, Vol. 229, pp. 178

Fritsch, J. H. (1824) Berl. Jahrb, pp. 252

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Hack and Sevelli (1979) Astronomy and Asrtophysics Vol. 75
pp. 316

Handbury and Williams (1976) Ap. and Space Sci., Vol 45
pp. 439

Hill et al. (1975) Mem. R. astr. Soc. Vol. 79 pp. 131

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Sahade and Wood (1978) "Interacting Binaries"

Strand (1959) A. J., Vol. 64 pp. 346

Van De Kamp (1878) A. J., Vol. 83 pp. 975

Vogel and Eberhard (1902) Sitz., Ber. Preuss. Akad. D. Wiss

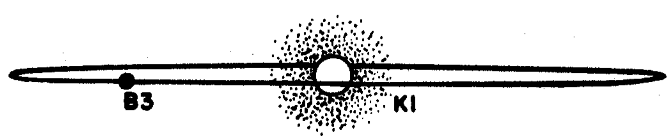
Wilson (1971) Ap. J., Vol. 170 pp. 529

Wood (1958) Trans. I. A. U. X pp. 625

Wright (1970) Vistas in Astronomy, Vol. 12

**31** (Omicron-1 Cygni) Position 20120n4635. Mag 3.76; spectrum gK1 or K2 II. This is the primary star of a fine wide color-contrast group which forms a very attractive sight for the low power telescope. The 5th magnitude star 30 Cygni lies 338" distant, and a closer companion of the 7th magnitude is 107" away. Both stars are noticeably bluish (spectra A3 and B5) and contrast strongly with the bright golden tint of the primary. The group is probably only an optical one. 31 Cygni itself shows no measurable proper motion or parallax; the radial velocity is about 4½ miles per second in approach. For 30 Cygni the catalog values are: Annual proper motion = 0.01"; radial velocity 12 miles per second in approach; parallax = .002".

The primary star is an eclipsing variable (V695) with the long period of 10.42 years or 3802.84 days, and a magnitude range (photographic) of 4.9 to 5.3. The K-star is an orange giant with a diameter of about 150 suns; it is evidently surrounded by a huge gaseous "corona" more than double the size of the star itself. The spectral type of the small star is given by various authorities as B3, B5, or B8; the Arizona-Tonantzintla Catalogue (1965) has B3 V. The B-star may be about 5 times the size of the Sun. From the spectra, the total light of both stars is computed to be about 500 times the light of the Sun.




**31 CYGNI— Schematic Model**

The two stars are 1.2 billion miles apart, and the orbit is oriented nearly edge-on, so that the smaller blue star is totally eclipsed by the giant once in each revolution. This phenomenon begins with an "atmospheric eclipse" in which the radiation of the small star must come through gradually deeper layers of the giant's atmosphere. Total eclipse lasts for 63 days; the atmospheric eclipses each last about 2½ months. Dates of beginning of totality are: January 10, 1962, June 9, 1972, etc.

Data from ***Burnham's Celestial Handbook***, by Robert Burnham, Jr.

## INSTRUCTIONS FOR UBV PEP EPSILON AURIGAE OBSERVERS

1. Epsilon Aurigae - BS 1605, $M_v$ = +3 .0 to +3.8
   SPEC- FO, PERIOD = 27.1 yr.
   RA (1950) = 4 Hr. 58 Min
   DEC(1950) = + 43° 45'

   Comparison Star
   Lambda Aurigae - BS 1729, $M_v$ = +4.7, SPEC - GO
   RA (1950) = 5 Hr. 15 Min
   DEC(1950) = + 40° 03'

2. Please note the following:

   A. Beware of photocell saturation.
   B. For photon counting systems, be sure to account for pulse coincidence (i.e., dead time).
   C. You must determine your extinction coefficients each observing session.
   D. Please determine your transformation coefficients and transform your data to standard UBV. If you have any problems or questions please write to HOPKINS PHOENIX OBSERVATORY, 7812 W. Clayton Dr., Phoenix, Arizona 85033 USA.

3. Please use the following format for submitting data:

EPSILON AURIGAE/LAMBDA AURIGAE
DATA REPORT

NAME: (YOUR NAME) REPORT DATE: (DATE REPORT SUBMITTED)

OBSERVATORY: (OBS. NAME) SOLID STATE/PMT: (SS OR PMT)

YEAR: (YEAR OBS. WERE MADE) PMT HV: (-XXX VDC, FOR PMT ONLY)

| MONTH | DOUBLE DATE | UNIVERSAL TIME | J.D. (GEO) 2,440,000 + | HELIO CORR. | FILTER | $\Delta$M | DIAPH | NOTE |
|---|---|---|---|---|---|---|---|---|
| (MAY) | (5/6) | (4:07) | ----.---- | (opt) | (V) | (1.653) | (60") | (1) |

NOTES: 1. Helio is optional. 2. $\Delta$M = 2.5 Log (VAR/COMP)
Please give M to three places if practical.

4. If you would like some blank DATA REPORT forms, send $2.00 (US) for 20, to HOPKINS PHOENIX OBSERVATORY, 7812 W. Clayton Dr. Phoenix, Arizona 85033 USA

## 1982-1984 EPSILON AURIGAE ECLIPSE

## OBSERVERS INFORMATION SHEET

**************

NAME: ____________________________________________

MAILING ADDRESS: __________________________________

__________________________________

OBSERVATORY NAME: ________________________________

OBSERVATORY LOCATION (CLOSEST TOWN): ______________

LATITUDE: ______________ LONGITUDE: ______________

ALTITUDE: ______________ TELESCOPE: ______________

PEP EQUIPMENT:
DETECTOR: ______________ AMPL/PHOTON COUNTER: ______

DATA LOGGING: COUNTER____, CHART RECORDER____, METER__
V/F - COUNTER_____, OTHER______________

FILTERS: V-________, B-________, U-__________

COMPUTER SYSTEM: __________________________________

REMARKS: __________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

PLEASE COMPLETE THE ABOVE FORM AS SOON AS POSSIBLE AS SEND TO THE HOPKINS PHOENIX OBSERVATORY, 7812 W. CLAYTON DR., PHOENIX, ARIZONA 85033 USA.

Epsilon Aurigae Eclipse Campaign Newsletter

SUBSCRIPTION FORM

There is no free lunch in astrophysics either. The costs of photocopying, and mailing this series of newsletters must rely in part upon the interest of its readers. We have received to date support from the AAS, NASA and JILA, with the understanding that the Newsletters become self-supporting. To this end we must now request your supporting donation. We are asking US$5. to cover the expenses for the Newsletters for the balance of 1982, and possibly beyond, costs permitting. Foreign readers who may have difficulty remitting US funds should write to J. Hopkins indicating their situation.

Kindly remit this form & your subscription payment to:

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Hopkins-Phoenix Observatory
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Your response by Sept. 1 would be greatly appreciated.