[107.05] Out-of Eclipse UBV Variations of epsilon Aurigae [F0Iap+?]

J. Hopkins (Hopkins Phoenix Observatory), R.E. Stencel (University of Denver Astronomy)

The Hopkins-Phoenix Observatory

An un-cooled single channel 1P21 photomultiplier photon counting system with standard UBV filters, on a permanently mounted C-8 & located in light polluted Phoenix, AZ

ABSTRACT

Epsilon Aurigae is a binary star system that eclipses once every 27.1 years. The next eclipse is predicted to begin in 2009. The eclipse is flat-bottomed and lasts nearly two years. In the high mass model, the primary star is an F supergiant, but the nature of the eclipsing object is poorly determined. During the 1982 - 1984 eclipse, a world-wide monitoring campaign was formed to observe the system with modern equipment. Despite a wealth of photometric, spectroscopic and polarimetric data, the nature of the eclipsing body is still debatable. To make matters more interesting, a mid-eclipse brightening was seen by several observers, including observations from space, discounting an earthly atmospheric extinction effect. Previous eclipse data also shows a mid-eclipse brightening. The primary F star appears to have pulsations, but most of the published data for the star system has been taken during eclipses. There are few data taken between eclipses. The Hopkins Phoenix Observatory has been obtaining UBV data of the star system out-of-eclipse since 1984. This paper examines the out-of-eclipse data and light curves to date, and presents possible pulsation periods with amplitudes. These data should provide a better baseline for the next eclipse, including any pulsation role in mid-eclipse brightening. Persons interested in participating in the upcoming eclipse campaign can contact co-author Stencel for a reference copy of the 1985 workshop on the eclipse of epsilon Aurigae.

INTRODUCTION

The ultra-long period [27.1 year] eclipsing binary, ε Aurigae [F0Iap + ??!] is, arguably one of most puzzling stars known. The earliest eclipse was described by Fritsch in 1821, and subsequent eclipses [1848, 1875, 1928, 1955] were analyzed by Kuiper, Struve, Stromgren, Hack, Huang [1965] and others, with assorted models including transparent companions, shell stars, black holes and, finally, a huge disk for its secondary. Frank Bradshaw Wood [1958, 1985] summarized the pre-1984 eclipse efforts, and Stencel [1985] documented efforts during the 1982-1984 eclipse campaign. *Shapley [1915, 1928] noted an out of eclipse variation of 0.3 mag with a period of approximately 355 days.*

The next eclipse is predicted to begin in 2009. The eclipse is flat-bottomed and lasts nearly two years. In the high mass model [Carroll et al. 1991], the primary star is an F supergiant, but the nature of the eclipsing object is poorly determined. During the 1982 - 1984 eclipse of epsilon Aurigae, the estimated times of contact varied due to the light curve variation at, or close to, the contact times. Close to the middle of the eclipse a significant brightening was reported by multiple observers and at multiple wavelengths. To help determine more accurate contact times, evaluate system interaction during first and fourth contact, and to shed light on the mid-eclipse brightening, out-of-eclipse data are needed.

The Hopkins Phoenix Observatory started observing epsilon Auriage beginning with the 1982-1984 eclipse. Continued UBV photometry is planned through the next eclipse, which starts in 2009. Future plans include obtaining photometry data in the infrared bands as well as the UBV bands.

References:

•Carroll, S., Guinan, E., McCook, G. and Donahue, R. 1991 Ap.J. 367: 278, “Interpreting epsilon Aurigae”

•Huang, S-S., 1965 Ap.J. 141: 976, “An Interpretation of epsilon Aurigae.

•Kemp, J. et al. 1986 Ap.J. 300: L11, “Epsilon Aurigae - Polarization, light curves, and geometry of the 1982-1984 eclipse

•Shapley, H. 1915, Princeton Obs. Contrib. No.3

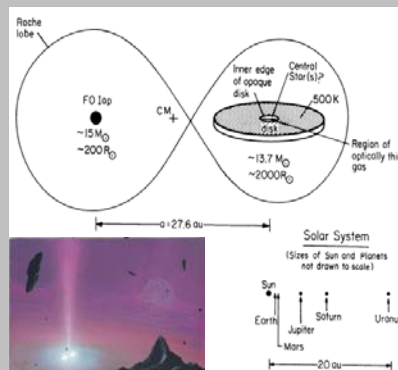
•Shapley, H. 1928, Harvard Obs. Bull. 858: 5, “On the Variability of the Maximum Light of Epsilon Aurigae”

•Stencel, R., ed. “The 1982-84 Eclipse of Epsilon Aurigae”, NASA Con Publ. 2384, QB823.R43, NASA, Washington DC.

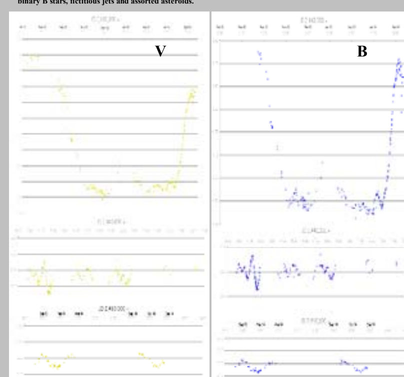
•Wood, F.B. 1958 Trans. IAU X, 625.

•Wood, F.B. in “The 1982-84 Eclipse of Epsilon Aurigae”, ed. R.Stence NASA Conf. Publ. 2384, NASA, Washington DC.

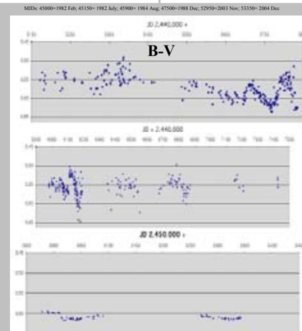
Figure 1: The epsilon Aur system (Carroll et al. 1991 Ap.J. 367: 278)

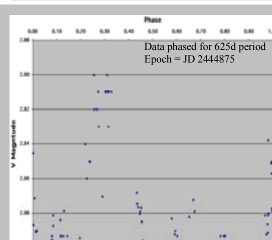


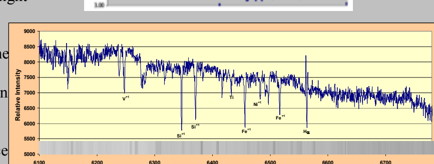
Artwork by D.Egge (with permission), showing yellow supergiant (upper right), hemisphere above plane of disk, with putative binary B stars, fictitious jets and assorted asteroids.



MJDs: 45000=1982 Feb; 45150= 1982 July; 45900= 1984 Aug; 47500=1988 Dec; 52950=2003 Nov; 53350= 2004 Dec







H-α region spectrum of epsilon Aur obtained by Dale Mais 12/04

METHOD:

The Hopkins Phoenix Observatory photometry system was calibrated and color transformation coefficients determined. Differential photometry was done using λ Aurigae as the comparison star. Typical sequence was three comparison star+sky readings in each filter followed by one sky reading next to the comparison star for each filter. Next this was repeated for the program star. Another set of comparison star data was then taken with the process repeated for a total of three sets of program star data. The three star+sky data were averaged, dead time corrected and the sky reading subtracted for each star and filter. The raw data was then reduced to provide initial magnitudes of the four comparison star values and three program star values for each filter. The difference between each program star magnitude and the averaged bracketed comparison star magnitudes was then determined for each filter and set. The three resulting program star magnitudes for each filter were then averaged and a standard deviation determined. Typical standard deviation was 0.01 magnitude or better. Most observations were done close to the meridian. Assumed magnitudes of the comparison star λ Aurigae are: V= 4.71, B= 5.34, U= 5.46. As shown in the figures, out of eclipse variations of ~0.2[V], ~0.3[B] and ~0.4[U] magnitudes were found.

An epsilon Aurigae data and information website has been set up: http://www.hposoft.com/Astro/PEP/EpsilonAurigae.html

DISCUSSION:

Time series analysis was attempted with varying results. A manual overlaying of peaks showed a possible 625 day period of a significant increase in brightness. There may be other harmonics or sub-harmonics, however. The peaks are brighter than visual magnitude 3.0 Further analysis is underway, along with new spectroscopic monitoring.

Peaks w/625 day period

JD 2,444,875	27 September 1981 (epoch)
JD 2,445,500	14 June 1983 (mid-eclipse brightening)
JD 2,446,125	28 February 1985 (observed)
JD 2,446,750	15 November 1986 (observed)
No data from 1988 to 2003	
JD 2,453,000	26 December 2003 (observed)
JD 2,453,625	11 September 2005 (Next?)

INTERPRETATION: Some of the possible causes of this long period variation could include: [a] pulsation of the F star [Cepheid like mode?]; [b] beating of separate shorter periods; [c] fluctuations in mass transfer/nebula illumination in the system; [c] the binary B star orbital period, or [d] a period associated with the inner orbits of the disk near the binary B stars. Clearly, further work will be needed to clarify this.

Proposal for a Joint Discussion to be held at the 2006 IAU General Assembly, Prague, 14-28 Aug 2006

Working title: THE 2009-2011 ECLIPSE OF EPSILON AURIGAE

VERY PRELIMINARY PROGRAM[30 min; else 15 min talks]:

*List of topics, **potential speaker[s]** and their nationalities:*

•Progress since the 1984 eclipse: Guinan, USA

•Photometry overview: ***your name here? –contact R.Stencel***

--optical: Cha, China; Ziznovsky, Slovakia

--polarimetry: Henson, USA

--infrared: Taranova, Russia; Backman, USA

•Spectroscopy overview: ***your name here? –contact R.Stencel***

--ultraviolet: Lambert, USA

--Ca H&K: Subrahmanyan, India

--H-alpha: Arellano-Ferro, Mexico; Gimenez, Spain; Cha, China

--CO lines: Hinkle, USA

--spectrophotometry: Ferluga, Italy; Bondar, Ukraine; Lutz, USA

--velocities and abundances: Chun, Korea

•Theory overview: ***your name here? –contact R.Stencel***

--Pulsation analysis: Maeder, Switzerland; Guo, China; Bono, Italy

--Disk/binary models: Wilson, R. USA; Lissauer, USA; Saito, Japan; Kumar, UK

•Related systems: ***your name here? –contact R.Stencel***

--Algols: Richards, USA

--EE Cep: Mikoljewski or Graczyk, Poland

--Extragalactic systems: Andrez Udalski [OGLE project], Poland

•The 2009 International Campaign: Stencel, USA

•For a free copy of the NASA conference publication #2384, "The 1982-84 Eclipse of Epsilon Aurigae", please email rstencel@du.edu, and provide your complete airmail address.