Long-Period Eclipsing Binary System Epsilon Aurigae Eclipse Campaign

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Presented at the May 2006 Society for Astronomical Sciences symposium, Big Bear CA

Abstract

Epsilon Aurigae (Vmax = 2.99) is an eclipsing binary star system with the longest orbital period known (27.1 years or 9,886 days). The next eclipse of this unique object is due summer 2009. With such a long orbital period, the actual eclipse might be expected to be short, but is just the opposite, lasting nearly 2 years (ca. 714 days). To a first approximation, this indicates the eclipsing body is of gigantic proportions, on the order of 2,000 solar radii. The exact nature of Eps Aur is still not fully resolved. A successful observing campaign was organized during the last eclipse, 1982-1984. Amateur and professional astronomers around the world contributed photometry, polarimetry, and spectroscopy data. Despite the strong effort, some questions still remain. Efforts have begun for a new eclipse campaign in 2009-2011. Out-of-eclipse observations are being made. A dedicated web site has been set up as a focal point.

1. Introduction and Background

Epsilon Aurigae, nominally a 3rd-magnitude naked-eye star in the northern sky, holds a secret that has defied complete understanding for over 185 years. Every 27.1 years, the primary F star undergoes a diminution of its light for the extraordinary period of about 714 days. A cold, non-luminous obscuring body passes across our line of sight, reducing the light of the primary by one-half, or about 0.8 magnitude. The secondary object is never seen – the light of the primary star is diminished equally at all visible wavelengths, while no spectrum of the secondary is noted. From the length of the eclipse, the estimated size of the secondary is truly gigantic – over 2,000 solar radii. Because of the length of time between eclipses, the chance to study this object comes only once or twice in an average scientific career. So each cycle brings a new generation of observers, with more sophisticated techniques.

2. History – Observational Timeline

The history of Epsilon Aurigae may be divided into several observational eras: 19th Century – Visual Observations; Early to mid 20th Century – Ground-Based Observations; and Late 20th Century to Present – Ground and Space-Based Observations.

19th Century – Discovery and Visual Observations

The light variation of Epsilon Aurigae was evidently first noted by J. Fritsch, a German observer, in 1821. He sent his observations to other observers, but they apparently attracted little notice until the 1840s, when a second eclipse cycle was observed. Subsequently, through the next cycle, occurring in the 1870s, the star was carefully watched. Apart from the three long eclipses, the star showed no significant out-of-eclipse variation visually. The main features of the eclipse cycle were established: a slow decline by about 0.8 magnitude over 190 days, steady light during the total phase for about 330 days, and then a slow recovery to original brightness over 190 days, with the two-year eclipse cycle repeating at intervals of 27.1 years. An attempt to classify the star with other known long-period or Algol-type variables lead to more questions than answers. Markwick (1904) in Britain was the last of this era to report visual observations; his plot of light intensity over the period 1888 – 1904 is shown for comparison in Figure 1(a) against other, modern light curves. Unfortunately, he missed most of the important eclipse features.

Early 20th Century – Ground-Based Instrumentation and Observations

Beginning with the 1900-1902 eclipse, with the availability of photographic and spectroscopic equipment, more was learned. Spectroscopic studies were initiated at Yerkes Observatory, and in Germany, H. Vogel used the well-equipped facilities he had established at the Potsdam Observatory. Vogel determined he had detected Doppler-shifted spectral lines, and confidently announced that Eps Aur was a spectroscopic binary. He set his colleague, H. Ludendorff to work on the problem, who examined all the available observations in a 1904 report. Other workers began to make spectroscopic, and later, photoelectric observations. After the 1928-30 eclipse cycle, C.M. Huffer (1932) and M. Güssow (1936) published extensive reports. Güssow published a detailed light curve, Fig. 1(b), based on photoelectric observations by herself, J. Stebbins, and C.M. Huffer (reprinted in Reddy, 1982).

O. Struve, beginning his studies of eclipsing binaries in 1924, observed Eps Aur spectroscopically, and in 1937 announced a model with his colleagues at Yerkes (Kuiper, Struve, and Strömgren, 1937) which postulated a very large, semi-transparent secondary star (the "I" star) passing in front of the F primary. The gasses of this object were supposed to be subject to intense ionizing radiation from the F primary, producing a layer in its atmosphere that would attenuate the light from the primary equally at all wavelengths, in accordance with observations. However, this model came in for criticism almost immediately, as the radiation from the primary would be insufficient to produce the necessary depth of opacity. Later this model was modified to include clouds or rings of particles. However, to maintain equal opacity at all wavelengths, the material could not be gas molecules or even fine dust, but larger solid particles.

For the 1955-57 eclipse cycle, F. B. Wood and his associates at Flower and Cook Observatory of the U. of Pennsylvania organized an international cooperative observing campaign, under the auspices of IAU Commission 42. Ten bulletins were published and distributed to interested observers as the eclipse progressed. Observations were also reported for another long-period eclipsing binary, VV CEP. Wood's student L. Fredrick published a comprehensive report in 1960.

In 1962, O. Struve stated, "*The history of the eclipsing binary Eps Aurigae is in many respects the history of astrophysics since the beginning of the 20th century.*" During the 1960s and 1970s, astronomers such as M. Hack, S. Huang, and Z. Kopal extended the existing models and suggested new ones. The proposed models underwent many changes and adjustments as new information became available through the middle years of the century. Sahade and Wood (1978) published a review of the 1928-30 and 1955-57 results, giving a 1970 comparison light curve by Glyndenkerne, Fig. 1(c), along with a good review of the known data.

Late 20th Century to Present – Ground- and Space-Based Observations

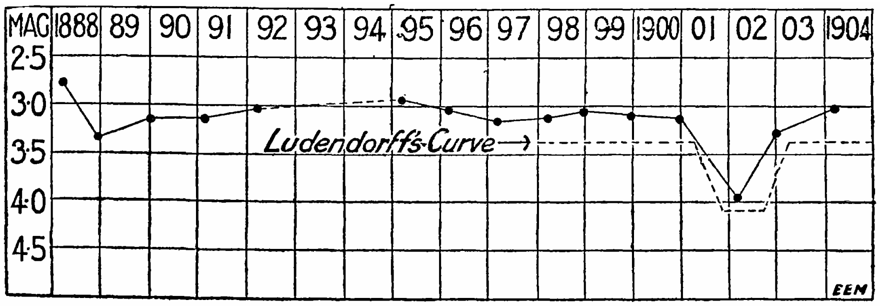
By the late 1970s, both new ground-based and space-based techniques and instrumentation became available. The space satellite resources enabled observations to be made at Infrared and Ultraviolet (IR and UV) wavelengths not available to ground-based observatories. Leading up to and during the 1982-84 eclipse cycle, popular level articles were published by F. J. Reddy (1982) and D. Darling (1983), outlining the leading theories and models.

For the 1982-84 Eps Aur eclipse, the fledgling International Amateur-Professional Photoelectric Photometry (IAPPP) organization, headed by Dr. Douglas Hall of Vanderbilt University, established a cooperative international observing program. Initially, the Campaign Newsletter editor for photoelectric photometry was Russ Genet, then Jeff Hopkins of Hopkins Phoenix Observatory took responsibility. Dr. Robert Stencel, of NASA-Headquarters (later at Denver University), was the editor for spectroscopy, polarimetry, and space-based observations. Altogether, 13 Newsletters were published and sent to interested observers around the world. Up-to-the-minute results and data were included in each newsletter, published about every quarter. (Hopkins 1984, 1985, 1987.)

After the eclipse ended, a NASA-sponsored Conference held in Tucson, Arizona in 1985 was attended by over 50 people (Fig. 2 and 3) and included many interesting papers (Stencel 1985). A composite 1982-4 light curve from Hopkins Phoenix Observatory is shown in Fig. 1(d). Other review articles were published by M. Hack (1984), R. Chapman (1985), and A. MacRoberts (1985, 1988).

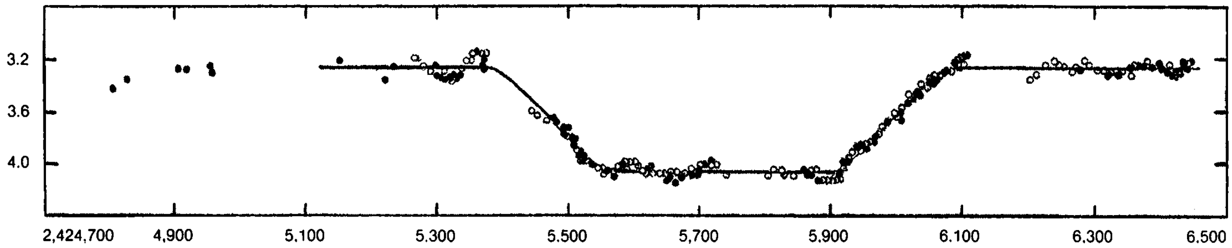
a.) 1888 – 1904 (JD 2,410,600,to JD2,415,600)

Ref: Markwick, *MNRAS* Vol. 64 (1904) p. 85. (Visual observations).



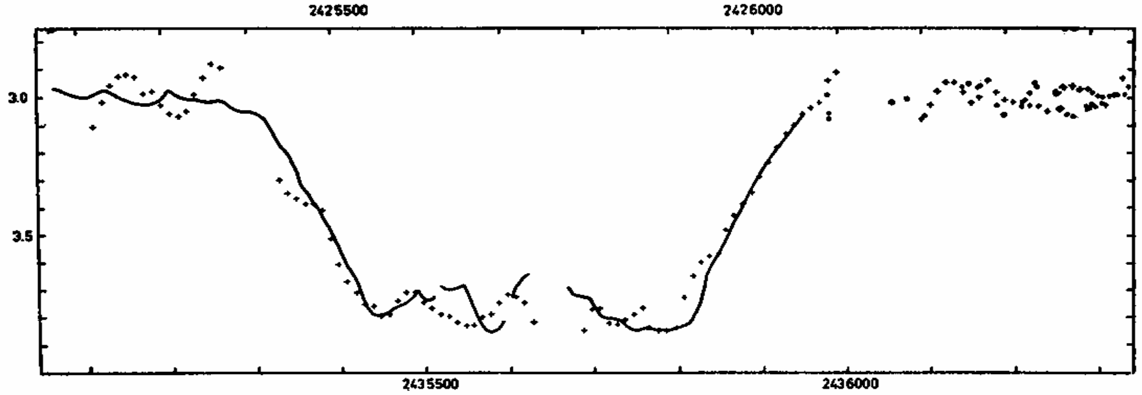
b.) 1928-30 ECLIPSE – JD 2,424,700 to JD 2,426,500)

Ref: Reddy, *Sky & Telescope* May 1982 p. 460. (Data from Güssow, Stebbins, and Huffer).



c.) 1928-30 and 1955-57 ECLIPSES JD 2,425,500 to 2,426,000 (+) and JD 2,435,500 to 2,436,000 (smooth curve + dots)

Ref: Sahade and Wood, *Interacting Binary Stars* (1978), p. 153. (Data from Glyndenkerne 1970).



d.) 1982-84 ECLIPSE – JD 2,445,151 to 2,445,912

Ref: MacRoberts, *Sky & Telescope* Dec. 1985 p. 527. (Data from J. Hopkins).

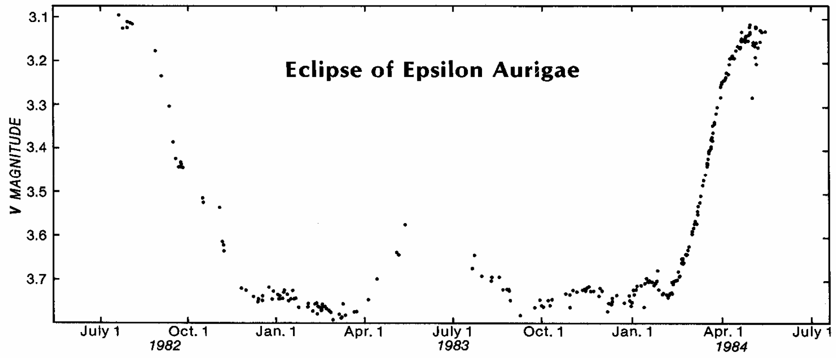


Figure 1. Epsilon Aurigae Light Curves 1888 – 1984.

Figure 2. 1985 AAS Meeting in Tucson, Arizona. (Epsilon Aurigae took top billing over the Hubble Space Telescope.)

The 1990s and Beyond

Since the last eclipse cycle, sporadic observations of the Eps Aur system have been accomplished with space-based instruments by various groups of observers, including a new generation of infrared instruments and Hubble Space Telescope. The space-borne observations, while encouraging, are not easy to analyze. While at least one group has confidently declared the "mystery" of Eps Aur has been "solved", yet more work needs to be accomplished to wring out the details and confirm the latest models.

Ground-based observers have continued to monitor the small-amplitude (ca. 0.2 magn.) fluctuations of the primary star. A renewed effort was started at the Hopkins Phoenix Observatory beginning in the fall of 2003 to obtain out-of-eclipse UBV photometry data. During the winter of 2005/2006, J and H band infrared observations have been added. Multiple periodicities have been determined (Hopkins 2006).

Figure 3. Group Photo – Tucson 1985 Conference Attendees.

3. Prospects For The 2009-11 Eclipse

J. Hopkins and R. Stencel have posted predicted event times for the upcoming 2009-11 Epsilon Aurigae eclipse cycle on their respective web pages (see the Web Resources list below). Plans are being drawn for a coordinated observing campaign, and a dedicated web site is to be announced shortly. The focus for the upcoming campaign will be on electronic dissemination of campaign information via e-mail and the web pages. Guidelines for observations, report forms, etc. are being developed and will be posted. Amateur observers in particular need to be aware of proper observing procedures, use of the standard comparison star (Lambda Aur), and use of standard filters. While continuous coverage of observations is desirable, the emphasis will be on quality of observations, rather than quantity. Eps Aur is a nearly ideal object for visual observers, small telescopes, and CCD cameras, because it is bright, has a long observing season, and a leisurely pace of events. It is an excellent target for training and developing measurement skills. Along with times of ingress and egress, perhaps the most important observations will help refine our knowledge of the mid-eclipse brightening and how it changes. Naturally mid-eclipse occurs during summer months when Auriga will be low, adding to the challenge.

Photoelectric Photometry Recommendations

Amateur astronomers with modest observing equipment and backyard observatories have a unique opportunity to make a valuable contribution during the upcoming campaign. Concentrated photometry in the ultraviolet (UV) through infrared (IR) bands is encouraged. Observations from multiple observatories are encouraged, particularly from higher latitude locations. Overlapping data will help provide more complete coverage of the star system, before, and during the ingress, mid-eclipse, egress and post-eclipse phases. Coverage of the mid-eclipse period is especially desirable.

It is very important that filter photometry be properly accomplished, and the observer's photometric system is properly calibrated to provide color-corrected data. Uncalibrated data will not be useful. The photometer system must be calibrated and the color transformation coefficients determined and used in the data reduction. While single-channel photometry may be easiest, CCD photometry is also encouraged. For best accuracy, differential photometry should be performed. Due to Eps Aur's brightness (3rd magnitude) and the angular distance from the commonly used comparison star (Lambda Aur), CCD photometry may be difficult. For practise, observers should attempt to measure Deneb (alpha Cygni) during summer seasons.

Practice before the eclipse period is suggested to refine observing techniques and at the same time produce valuable data. Single-channel photometry is ideal for this. In addition to photomultiplier tube (PMT) UBV photometry, the solid-state Optec SSP-3 photometer unit can provide BVRI data, and the Optec SSP-4 unit can provide Infrared J and H band photometry. It is recommended that while a 10 inch (25 cm) aperture telescope can be used for J and H band photometry of Epsilon Aurigae, the signal-to-noise ratio will not be good. A minimum of a 12 inch (30 cm) aperture telescope is recommended for photometry of Epsilon Aurigae with the SSP-4 photometer. For PMT (UBV) and SSP-3 (BVRI) photometry, an 8 inch (20 cm) aperture telescope is more than adequate. Again, calibrated data is required.

4. Web Resources

Anyone interested in contributing photometric data for Epsilon Aurigae, please view the Epsilon Aurigae web site and contact Jeff Hopkins at phxjeff@hposoft.com.

Hopkins Phoenix Observatory (HPO) pages:
http://www.hposoft.com/Astro/PEP/EpsilonAurigae.html

Dr. Robert Stencel (U. of Denver) web pages:
http://www.du.edu/~rstencel/epsaur.htm

5. Acknowledgments – Research Notes

The idea for this paper grew out of a talk on “Serious Astronomy” presented by Jeff Hopkins to the Saguaro Astronomy Club (SAC), Phoenix Arizona (Hopkins 2005). The lead author (Lucas) discovered there are close to 300 published articles relating to this fascinating object. Only a few of the most interesting are cited here.

The majority of the references cited herein are available on the internet. Research for this article made use of the SIMBAD astronomical database, and the NASA Astrophysics Data Services (NASA-ADS) web resources. A few journal articles were retrieved using the facilities of the Noble Science Library, Arizona State University, Tempe, Arizona, and the Burton Barr Central Public Library, Phoenix, Arizona. Jeff Hopkins supplied archive copies of the 1982-84 Epsilon Aurigae Eclipse Campaign Newsletters, and Dr. Robert Stencel supplied a copy of the NASA 1985 Conference Proceedings. These last materials are being scanned and will be made available electronically on the Eps Aur web pages.

6. Conclusions

Observations of Epsilon Aurigae stretch back over 185 years. Although successful international observing campaigns were waged during the 1950s and 1980s, the exact nature of this unique, very long period eclipsing binary system is still not fully established. Out-of-eclipse photometry is underway. Preparations have begun for a new observing campaign for the 2009-11 eclipse season. Interested amateur and professional observers are encouraged to contact the authors and visit the web pages for additional information.

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