

Epsilon Aurigae, 2009:

The eclipse begins – observing campaign status

Robert E. Stencel
University of Denver Observatories
Dept. Astronomy & Physics, Univ. Denver, Denver CO 80208
rstencel@du.edu
&
Jeffrey L. Hopkins
Hopkins Phoenix Observatory
7812 W. Clayton Dr., Phoenix AZ 85033

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Abstract

The eclipse of 3rd magnitude epsilon Aurigae is forecast to begin during August 2009, reaching totality by year's end, based on all six prior eclipse events studied - 1982, 1955, 1930, 1902, 1874 and 1847. We have organized a campaign during the past several years in order to raise awareness about this rare opportunity, and to promote reporting of observations of all kinds. We have 40 registered participants, 76 people signed up for alert notices, plus numerous informal expressions of interest. Categories of observations being reported in Campaign Newsletters (11 since 2006) which include Photometry, Spectroscopy, Polarimetry, Interferometry and Citizen Science [website: www.hposoft.com/Campaign09.html]. In this presentation, we provide a brief update on the optical and near-IR photometry obtained to date. The nature of the short term light variations will be discussed in the context of mapping the eclipse behavior. Spectroscopy benefits from small telescope capabilities now widely available, along with traditional large telescope, higher dispersion work. Examples of each will be presented, along with the research objectives. Polarimetry provided key insights during the last eclipse, and we continue to promote the need for new data using this method. Finally, interferometry has come of age since the last eclipse, and a status report on this powerful method to directly detect the passing dark disk will be provided. Along with these traditional measurements, we will briefly discuss efforts to promote Citizen Science opportunities among the public, in coordination with AAVSO and as part of the International Year of Astronomy, IYA 2009.

1. Introduction

Epsilon Aurigae (ep-si-lon Awe-rye-gee) is a very long period eclipsing binary (Algol-like). The 27 year eclipse interval includes a nearly 2 year eclipse duration, wherein visual magnitude drops from 3.0 to 3.8. As of this year's SAS symposium, we're anticipating the start of the first eclipse of the millennium during August 2009, with totality reached during December 2009, and lasting ~15 months, through March 2011. The end of eclipse is expected during May 2011. This will be only the sixth documented eclipse in history (1983, 1956, 1930, 1902, 1874 and 1847). For additional detail about epsilon Aurigae, see Hopkins, Schanne and Stencel (2008), along with the book about the star by Hopkins & Stencel (2009), and a feature article in the May 2009 issue of *Sky & Telescope* magazine. Because this eclipse begins during the International Year of Astronomy (IYA), it has been adopted as an element of the Citizen Science component of the US-IYA activities, with AAVSO leadership.

The reason for the continuing interest in this binary has to do with the difficulty of determining the nature of the companion star – a dark, possibly quite massive disk shaped object, orbiting the seemingly normal F supergiant star that emits all the visible light.

With normal eclipsing binary star systems, one measures the brightness, changes and durations, to obtain radii, temperatures of each star in the pair. With spectroscopy, one can measure Doppler velocities, and solve for masses. This process calibrates all the important parameters that describe a star. The Vogt-Russell theorem says the mass, composition and age of a star uniquely determines the stellar structure, when normal laws of physics are applied. This procedure works well, except for epsilon Aurigae: the F supergiant star seems to have an equally massive, but invisible companion object. Thus, we have the problem of "hiding" all that mass.

Some of the observational questions under investigation for this eclipse include: (1) will the pre-eclipse low-amplitude light variations persist into

eclipse; (2) will the beginning and depth of eclipse match prior eclipse trends; (3) will the “mid-eclipse brightening” seen during the past two eclipses, recur. Additional basic questions are receiving attention: what is the true distance to the binary? HIPPARCOS says 625 pc (with a 72 percent uncertainty!). What is the physical diameter of the F supergiant star? Can we finally decide between the high mass model for the system (15 solar mass F supergiant star primary and massive dark disk of uncertain origin) or the low mass model (a rapidly evolving post-AGB “phony” supergiant star with a companion shrouded by recent Roche Lobe overflow mass loss)? Once again, epsilon Aurigae lies at the crossroads of modern astrophysics – providing evidence for details of high mass stellar evolution, plus an extreme accretion disk and possibly planet formation and destruction – all in one bright star package!

Numerous prior observational studies have shown the presence of additional absorptive material during eclipse. The prevailing model (Huang 1965 and thereafter) accounts for these data with a thin disk crossing the body of the F supergiant during eclipses (see Carroll et al. 1991).

In this paper, we will describe the observational efforts already underway, thanks to the interest of numerous observers worldwide, in advance of the eclipse anticipated to begin after mid 2009. The ensemble of data streams will help provide a context within which individual observations can help prove or disprove hypotheses about this mysterious system.

2. Photometry

Photometry is the measurement of light. During recent decades, single channel photometers have become readily available (e.g., the SSP-3 and SSP-4 units available from www.optecinc.com), and progress with CCD aperture photometry of faint stars has been made (see papers at this meeting). Photon counting photometers such as used at the Hopkins Phoenix Observatory have proved to be very accurate with even modest telescopes on the brighter stars.

A serious problem with epsilon Aurigae is that it is so bright for modern instruments that saturation and dead-time become problems. Everyone needs to be reminded that this eclipse is also a fine visual event – you can easily see epsilon Aurigae dim relative to nearby eta Aurigae ($V=3.2$) and zeta Aurigae ($V=3.8$), which comprise the “Kids” asterism near Capella. A light curve based on visual reports is assembled at the AAVSO Variable Star of the Season page for epsilon Aurigae (Jan. 2008).

Hopkins Phoenix Observatory has compiled one of the longest and most continuous UBVI observing records leading up to the oncoming eclipse (Figure

1), including 1982-1989 and 2003 to the present. As can be seen from the plot, epsilon Aurigae is anything but quiet between eclipses. The object of these observations is to see if the out-of-eclipse variations could be better understood. A key feature of the pre-eclipse light curves is the appearance of a quasi-periodic variation, recently showing a 65 day period, deduced with Peranso software (Hopkins et al. 2008). Interestingly, a long photometry record by Nha et al. (1993) showed similar variations, but with a longer characteristic period, closer to 95 days. Monitoring will help interpret in-eclipse fluctuations. If the acceleration trend persists, there may be exciting times ahead for the system within a few decades – perhaps destruction of a Jupiter-sized object within the accretion disk central region.

Beginning with the 2008/2009 season, more observers from around the world became involved with the upcoming eclipse. These observers have submitted UBVI and JH photometric data to the Campaign newsletters. While the Hopkins Phoenix Observatory uses a PMT based photon counter for UBVI photometry, others have used an Optec SSP-3 for BVRI data, an Optec SSP-4 for near infrared J and H and data, CCD photometry for BVRI data and DSLR CCD cameras for V data. Excellent photometric data have been reported by:

David Trowbridge (Tinyblue Observatory, Greenbank, Washington, USA)

Dr. Tiziano Colombo (S. Giovanni Gatano al Observatory, Pisa, Italy)

Richard Miles (Golden Hills Observatory, Stourton Caundle Dorset, England)

Paul Beckmann (Jim Beckmann Observatory, Mendota Heights, Minnesota, USA)

Des Loughney (Edinburg, Scotland),

Brian McCandless (Grand View Observatory, Elkton, Maryland, USA),

Frank J. Melillo (Holtsville, New York, USA).

These data have been reported in our Campaign Newsletter series, available free in .pdf format at our Campaign informational website: www.hposoft.com/Campaign09.html. Figure 2 shows a composite of V data from multiple observers. The quasi-periodicity of out-of-eclipse variations remains a mystery. Over the past several years, seasonal period analysis suggested the variation frequency to be increasing (Hopkins et al. 2008). The 2007/2008 season showed a period of around 65 days. This past season (2008/2009) appears to show a significant period of 148.6 days, again deduced using Peranso software - the Discrete Fourier Transform (Deeming) method, with V band data. Other bands yield a similar period. We continue to study these photometric period trends.

With the help of Denver U. grad student, Brian Kloppenborg, we've been pursuing J&H band photometry of epsilon Aurigae during early 2009. Using an SSP4 photometer on a very unusual 16 inch telescope, we have very preliminary evidence of declines in the J band during a time when the optical light was at a record local minimum near RJD 54900. Whereas we did double check that we measured full signal in J, by re-centering the star in the aperture repeatedly, these data probably need closer examination to be verified. Brian McCandless in Newsletter 11 reported some J band declines as well during this period, just when V was steeply falling. Spectroscopically, the J band contains Paschen beta and gamma lines, along with the CN Red 0-0 band, but whether these are active in epsilon Aurigae and causing the J band "dropouts" needs confirmation, perhaps because encroaching disk flotsam is the cause.

For completeness, we note that infrared spectrophotometric measures have been obtained with IRTF at Mauna Kea (SpeX – Stencel et al. Figure 3 – BASS – M. Sitko et al. U.Cinc. -- and MIRS – G. Orton et al., JPL) and the Spitzer Space Telescope (MIPS – S. Howell, NOAO). A recent X-ray measurement made by the European XMM satellite has been made (S.Wolk, CfA, private communication). Results of these observations will be reported elsewhere.

3. Spectroscopy

We're pleased to report that several professional observatories have resumed gathering high dispersion spectra of epsilon Aurigae as it approaches eclipse. In addition, the advent of affordable spectrographs like the LHIRES and SBIG spectrometers make amateur data collecting on bright objects relatively easy. Some of our most active observers include Jeff Hopkins (Phoenix), Lothar Schanne (Germany), Robin Leadbeater (UK), Joel Eaton (Nashville/TSU) and Elizabeth Griffin (Victoria/DAO). Several observers are concentrating on the H-alpha line near 6563Å, which shows rapid variations of its emission wings. Attempts to correlate the line attributes with the visual light curve have been frustrated by the complexity of the variations (see Hopkins & Stencel paper, this volume). Leadbeater and others are also monitoring the "blue" region of the spectrum, e.g. 4600Å, which Ferluga and Mangiacapra (1991) demonstrated is an excellent region for the appearance of "shell lines" during eclipse. Similarly, the resonance lines of sodium (D lines near 5900Å) and potassium (K I 7664/7699Å) have shown significant absorption strength increase during

portions of prior eclipses (Lambert & Sawyer, 1986), and monitoring of these is encouraged.

Very interesting radial velocity changes are seen at higher dispersion. Elizabeth Griffin (DAO) reported changes in the blue region between December 2008 and February 2009 that indicate "reverse P Cygni" profiles appear in difference spectra. These could be consistent with encroachment of the fringes of the disk onto the F star body as eclipse nears. This work highlights the findings of the long term radial velocity curve, discussed by Lambert and Sawyer (1986) and in new work by Stefanik et al. (2009). As mentioned above, by monitoring the strength of H-alpha, sodium, potassium lines, and in the blue region, evidence of the disk and its changes may be within reach this cycle. Joel Eaton at Tennessee State University has embarked on radial velocity monitoring with an automated spectroscopic telescope, which offers great promise for providing fiducial velocity data against which the light variations can be compared. Brian McCandless reported a brief appearance of He I emission in the 6678Å line during 2009 April, and observers are encouraged to look for the related He I lines at 4471, 5876 and 7065Å, arising from the UV source in the system studied with the IUE space telescope (HST's precursor) during last eclipse (see reports in Stencel, 1985). Similarly, Struve and Elvey (1930) reported transient emission in the core of the H-beta line during autumn 1928 (eclipse ingress). Ake (see Stencel, 1985) cites "extraordinary brightenings" in the ultraviolet near first and third contacts. Spectroscopic monitoring can help narrow the range of phases during which this UV window opens toward earth.

4. Polarimetry

Another powerful method in astronomy involves using polarized light. We use polarized lenses in sunglasses to reduce the light reflecting off water or other surfaces. The process of reflection can polarize light, terrestrially or from sources in space. The series of polarized light measurements reported by Jack Kemp and collaborators provides the best evidence so far for the shape and tilt of the disk. (Kemp et al. 1986; and see Kemp's report in Stencel, 1985).

Kemp invoked a tilted disk and slight non-edge-on orbital inclination to explain asymmetries in the polarization and previous light curves. Importantly, Kemp also suggested that the primary star is a non-radial pulsator with hotter polar regions tilted towards earth and/or an equatorial ring, to produce the asymmetric polarization observed.

Modern polarimeters need to observe epsilon Aurigae in order to support this interpretation. Several instruments are available, including the ESPaDOnS instrument at CFHT (Harrington & Kuhn (2009) which obtained data in 2006 on February 7 and 8. The observation shows a strong and complex $H\alpha$ signature. The polarization change is symmetric at line center and spans the width of the line. The polarization amplitude $\sim 1\%$ at the line center, not unlike other Be stars. Ideally, CFHT will pursue this opportunity, as indicated in a report by Nadine Manset in Campaign Newsletter 11.

5. Interferometry

One promising modern technology to apply to epsilon Aurigae's upcoming eclipse is called interferometry. This technique has been used for decades, but modern computer control and laser metrology has helped mature the methods to a point where a key, direct test of the Huang disk model is possible. By combining light from two or more telescopes, one can measure diameters at the milli-arcsecond level over telescope separation baselines of a hundred meters. Nordgren et al. (2001) reported the broadband optical diameter of epsilon Aurigae to be 2.18 milli-arcsec, using the Navy Prototype Optical Interferometer [NPOI]. Stencel et al. (2008) reported a Palomar Testbed Interferometer [PTI] infrared diameter of 2.27 milli-arcsecond using a north-south baseline, with indications of a larger diameter using a north-west baseline. Very recent 4 telescope observations at the Mt. Wilson-based Center for High Angular Resolution Astronomy [CHARA] array seem to indicate an asymmetry in the east-west axis, again as might be expected due to encroachment onto the F star of the disk's outer edges. The state of the art has advanced to a point where "closure phase imaging" is possible, although the results are highly dependent on assumptions used in the deconvolutions. In the best case, imaging interferometry may be able to "see" the bifurcation of the F star orb by the transiting disk during eclipse – directly testing the basic Huang model. Continuing observations are planned.

6. Citizen Science

We were involved in the 1982-84 eclipse events and re-started our efforts in 2003, in order to raise awareness of the pending eclipse and to promote observing and reporting, plus new theory. The websites for the campaign this cycle are: <http://www.hposoft.com/Campaign09.html>,

and <http://www.du.edu/~rstencel/epsaur.htm>. To date, eleven Campaign Newsletters have been produced since Sept. 2006. We encourage all interested parties to provide us with reports of your observations and analysis. Your photometry and spectroscopy reports are especially welcome.

In addition to formal reports like these, which we hope to continue, there is ample opportunity for "Citizen Science" by members of astronomy clubs and the general public. In cooperation with AAVSO and the US node of IYA, we hope to inspire interested persons to learn how to observe and record variable star brightness variations, with epsilon Aurigae as the major, unique opportunity starting in 2009. For details about this project, see website: <http://www.aavso.org/aavso/iya.shtml>.

An oddity concerning this eclipse is connected to our current economic turmoil. More than once it has been remarked that "certain rates are the most extreme since 1983" – bringing to mind events on earth during the last eclipse. In the recent months, when the Dow Jones stock market index dove to a record low and then recovered, in early March 2009, circa RJD 54900, epsilon Aurigae had already dimmed to a pre-eclipse faint record of $V=3.14$ on RJD 54890, and then brightened. Coincidence? Probably. Before you invest based on cycles in epsilon Aurigae, recognize that past returns are not a guarantee of future performance.

7. Conclusions

The eclipse is upon us! By promoting observation data of all kinds, we can hope to build a successful context for competition among the hypotheses that try to explain this mysterious star system. Whereas the F star is undoubtedly as or more complex than our Sun, the eclipsing body probably is the source of some of the activity detected thus far in epsilon Aurigae eclipse monitoring. Secular changes short and long term are being documented, and these will provide a rich ground for theory and debate as the long vigil prior to the 2036 eclipse begins in a couple of years. For more information and updates, see our campaign websites, plus, new for this year:

https://twitter.com/epsilon_Aurigae

8. Acknowledgements

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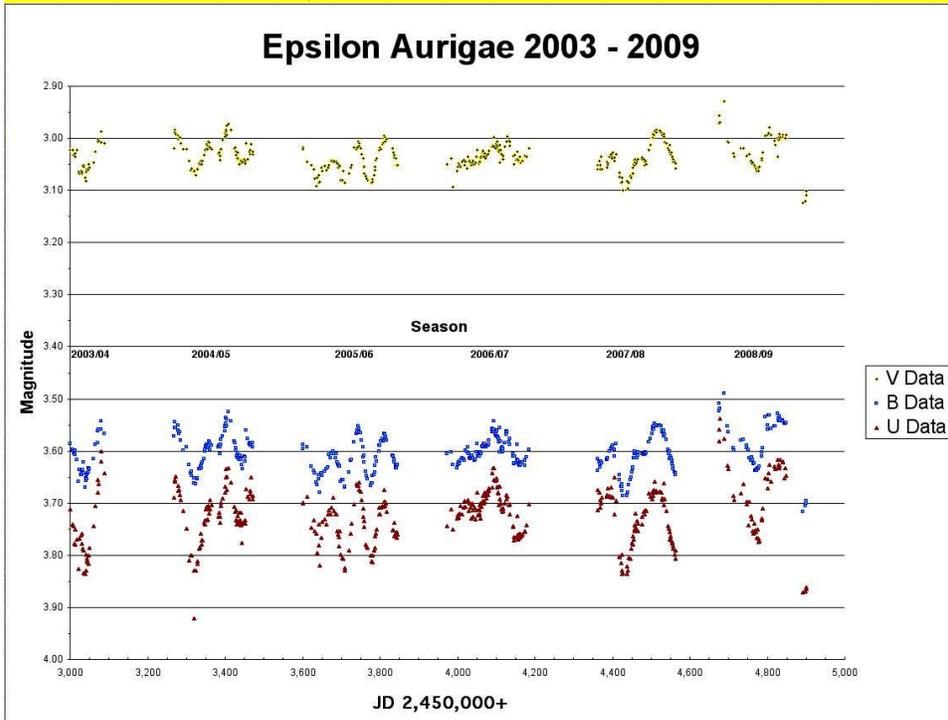


Figure 1. The UBV light curve of epsilon Aurigae between 2003 and 2009, obtained at the Hopkins Phoenix Observatory by Jeffrey Hopkins.

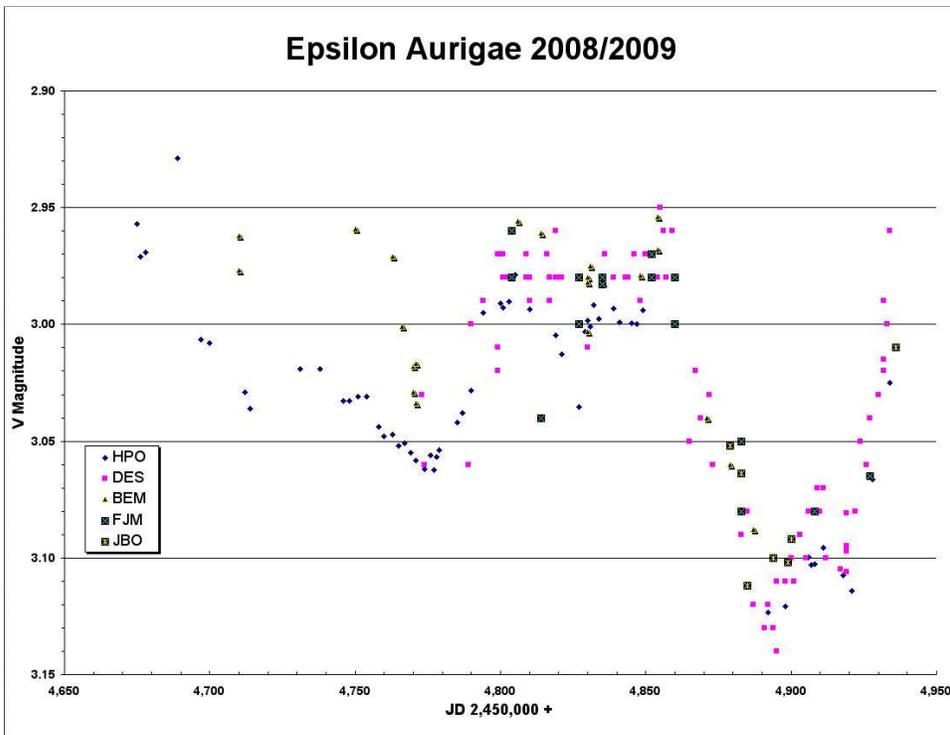


Figure 2. The composite V light curve of epsilon Aurigae for the 2008-2009 season, obtained by campaign observers J. Hopkins (HPO), D. Loughney (DES), B. McCandless (BEM), Frank Melillo (FJM) and Paul Beckmann (JBO).

FIGURE THREE, TWO COLUMNS WIDE, FILLING TOP HALF PAGE FIVE

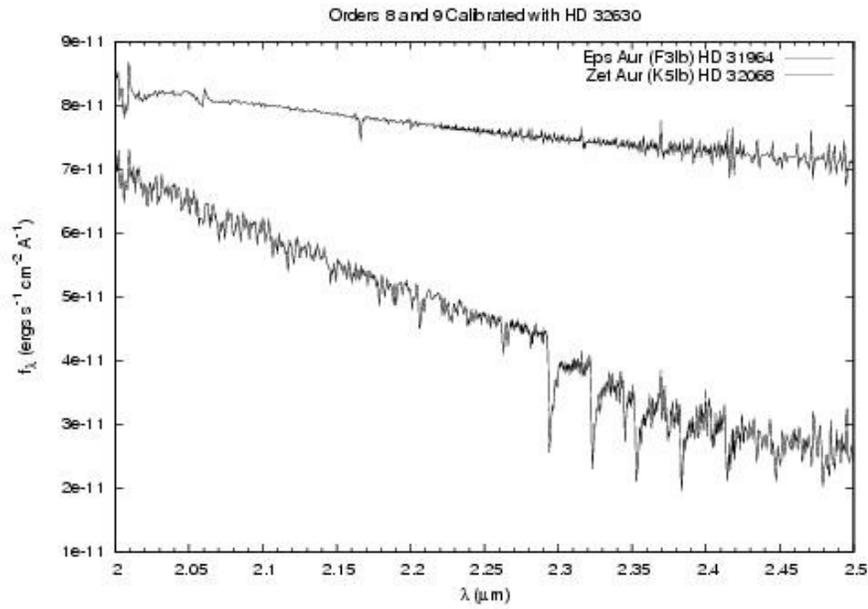


Figure 3. IRTF SpeX pre-eclipse spectrum of epsilon Aurigae (upper trace, 1/9/09, Stencel & Kloppenborg) compared with the much cooler supergiant, zeta Aurigae (lower trace) – the latter showing strong CO lines. The same CO features are expected to appear in the spectrum of epsilon Aurigae during eclipse.