

Epislon Aurigae, 2009: The eclipse begins – observing campaign status

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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 five prior eclipse events studied - 1982, 1955, 1930, 1902 and 1874. 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 36 registered participants, 74 people signed up for alert notices, plus numerous informal expressions of interest. Categories of observations being reported in Campaign Newsletters (11 since 2006) include Photometry, Spectroscopy, Polarimetry, Interferometry and Citizen Science. Website: www.hposoft.com/Campaign09.html. In this presentation, we'll provide a brief update on the optical and near-IR photometry obtained to date. The nature of the short term variation 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 high 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. Support for these efforts derives in part from a bequest to the University of Denver Astronomy Program by alumnus William Herschel Womble, for which we are grateful.

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 the 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 through March 2011. The end of eclipse is expected during May 2011. This will be only the fifth documented eclipse in history (1983, 1956, 1930, 1902 and 1874). For additional detail about epsilon Aurigae, see Hopkins, Schanne and Stencel (2008), along with the book about the star by Hopkins & Stencel (2009) and the May 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.

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 light.

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 indicating changes are expected; (3) will the “mid-eclipse brightening” seen during the past two eclipses recur. Additional basic facts are receiving attention: what is the true distance to the binary (Hipparcos says 625 pc)? What is the physical diameter of the F supergiant star, given new interferometric diameter measurements? 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 star “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 high mass stellar evolution, an extreme accretion disk and possibly planetary formation and destruction.

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.

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 in advance of the eclipse anticipated to begin later this year, thanks to the interest of numerous observers worldwide. 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 Aur ($V=3.2$) and zeta Aur ($V=3.8$), 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).

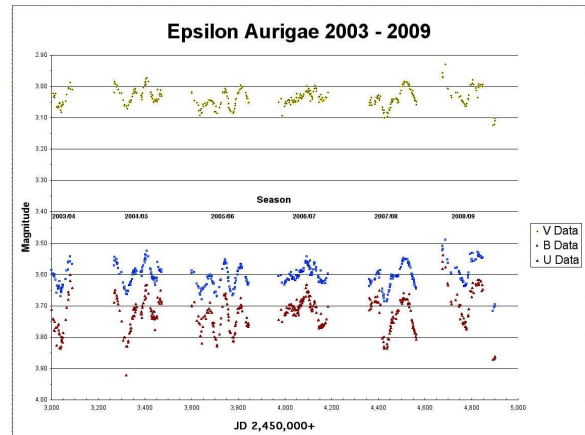


Figure 1. The UB light curve of epsilon Aurigae between 2003 and 2009, obtained at the Hopkins Phoenix Observatory by Jeffrey Hopkins.

Hopkins Phoenix Observatory has compiled one of the longest and most continuous UB light curves leading up to the oncoming eclipse (Figure 1), including 1982-1989 and 2003 to the present. As can be seen from the above 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, currently with a 65 day period, deduced with Peranso software. Interestingly, a long photometry record by Nha et al. (1993) showed similar variations but with a longer characteristic period, closer to 95 days. Monitoring this trend will help interpret in-eclipse fluctuations. If the 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 got involved for the upcoming eclipse. These observers have submitted photometry data to the Campaign for the UBVR and JH bands. While the Hopkins Phoenix Observatory uses a PMT based photon counter for UBVR photometry, others have used an Optec SSP-3 for BVR data, an Optec SSP-4 for near infrared J and H and data, CCD photometry for BVR 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 the
Campaign website:
www.hposoft.com/Campaign09.html. Figure 2 shows
a composite of V data from multiple observers.

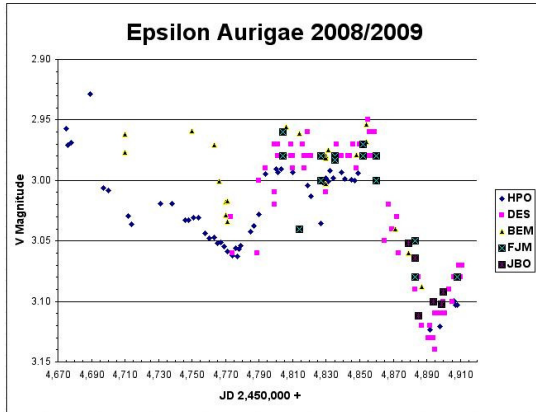


Figure 2. Composite 2008/09 season V data.

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With the help of grad student, Brian Kloppenborg, we've been pursuing J&H band photometry of epsilon Aur these past few months, (winter 2009). Using an SSP4 photometer on a very unusual 16 inch kluge of a telescope, we have very preliminary evidence of declines in the J band during a time when the optical light was at a record minimum. 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 also 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 eps Aur

and causing the J band “dropouts” needs confirmation, especially if 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 MIRSI – 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). Results of these observations will be reported elsewhere.

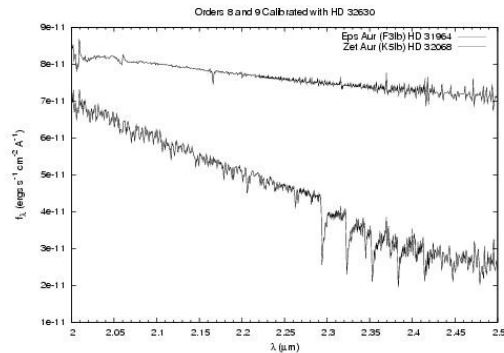


Figure 3. IRTF SpeX pre-eclipse spectrum of eps Aur (1/9/09, Stencel) compared with zeta Aur – the latter showing strong CO lines, expected to appear during eclipse of eps Aur next year.

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 object 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 6563A, 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. 4600A, 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 5900A) and potassium (7600A) have shown

significant absorption strength increase during portions of prior eclipses, 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 Stafanik 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. Stencel is involved with obtaining a series of infrared spectra using the SpeX instrument at IRTF to repeat the classic experiment of the last eclipse where the strength of 2.3 micron CO bands greatly increased at mid eclipse and persisted past end of visual eclipse phases – Figure 3, above.

4. Polarimetry

Another powerful method in astronomy involves using polarized light. We use polarized lenses in sunglasses to reduce the glare reflecting off water or heated 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 (Kemp et al. 1986; and see Kemp’s report in Stencel 1985), provides the best evidence for the shape and tilt of the disk so far.

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 α signature. The polarization change is symmetric at line center and spans the width of the line. The polarization amplitude ~1% at the line center, not unlike other Be stars.

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 an NPOI, optical diameter for epsilon Aurigae of 2.18 milli-arcsec. Stencel et al. (2008) reported a 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 CHARA 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. In the best case, imaging interferometry may be able to “see” the bifurcation of the F star orb by the transiting disk during eclipse. 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. 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.

In addition to formal reports like this which we hope to continue, there is ample opportunity for “Citizen Science” by members of the 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 a major opportunity starting in 2009. For details, 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.” However, in the recent months, when the DJIA dove to a record low then recovered, in early March, circa RJD 54900, epsilon Aurigae obliged by dimming to a pre-eclipse faint record of

3.14 on RJD 54890, and then brightening – Figure 2. Coincidence? Probably.

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 hypotheses that can 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 most of the activity detected thus far in epsilon Aurigae monitoring. Secular changes short and long term are being documented, and these will provide a rich ground for theory as the long vigil prior to the 2036 eclipse begins. For more information and updates, see our campaign websites and, new for this year:

https://twitter.com/epsilon_Aurigae

8. Acknowledgements

We are thrilled to thank the many participants and interested parties helping support the eclipse study. Stencel particularly acknowledges Bobby Buss, Brian Kloppenborg, Dale Mais, John Monnier, Ming Zhao and others for observing support, and is grateful to William Herschel Womble for a bequest in support of astronomy at the University of Denver, making this research feasible. Jeff Hopkins thanks... and we thank you, dear reader, for your interest!

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