

Tuesday June 3, 2008 – Text of remarks on epsilon Aurigae, prepared for AAS ST. LOUIS MEETING, IYA & Citizen Science panel discussion, section 68.

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The Science Case:

What could be simpler than an eclipsing binary star? As they orbit each other, it is relatively easy to measure brightness change and the duration of change, and, from simple geometric arguments, to obtain size and temperatures for each star in the binary. With the addition of Doppler spectroscopy, which measures orbital velocities, one can solve for mass of each star, using Kepler's third law.

The classic example of this is the so-called Demon Star, Algol, which exhibits 2 hour eclipses every 2.87 days. With such eclipsing binary stars, astronomers can calibrate important parameters that describe a star's structure. The Vogt-Russell theorem says the mass, composition and age uniquely determine the stellar structure, when normal laws of physics are applied. This theorem appears largely true, except for epsilon Aurigae - the real "Demon star". It's behavior has "bedeviled" astronomers for centuries.

The spectrum of epsilon Aurigae looks like a normal F supergiant star, estimated at about 12 to 15 times the mass of the Sun. The orbit data implies that the mass ratio in the binary is close to one, implying that the companion is about 12 to 14 solar masses as well. Epsilon Aurigae exhibits Algol-like eclipses every 27 years, which last for nearly 2 years. The next one starts in August 2009, and should run through May 2011.

The problem? The 12 to 14 solar mass second "star" is largely INVISIBLE! The best model (Huang, 1965) says the secondary is a huge dark disk, not a sphere. Such a shape needs a massive central object(s) to stabilize it.

Normal eclipsing binary star analysis suggests that the secondary is about 10 A.U. across (10 times the distance from the Earth to the Sun, or 930 million miles). It does not emit anywhere near the amount of light expected from a star of its size. Scientists are confident that it is not a black hole, because it hasn't been detected with X-ray observations (Einstein, Swift).

Epsilon Aurigae shows low amplitude quasi-periodic light variations, similar to Cepheid variable stars. Cepheid variable stars are close relatives of epsilon Aurigae, being high mass yellow stars prone to pulsation - a useful property in terms of their Period-Luminosity relationship. Currently the light variations in epsilon Aurigae are on a 67 day cycle, but **-KEY POINT-** these were nearer to 95 days during the last two decades. Something is accelerating in this system! At this rate, variations will become very rapid within six decades, perhaps cataclysmically so. Much of the relevant photometric data has been obtained by Jeff Hopkins of Phoenix Observatory, Arizona (<http://www.hposoft.com/EAur09/EAur0307Plots.html>), Il-Seong Nha of the Yonsei University Observatory, Korea and other observers (see <http://adsabs.harvard.edu/abs/1993ASPC...38..291N>).

But wait---there's more. Observations made during the last eclipse suggest that the F supergiant star may be shrinking by about 1/2 percent per year (noted in 1986 by Mamuro Saito and Masatoshi Kitamura at Tokyo Astronomical Observatory - <http://adsabs.harvard.edu/abs/1986Ap%26SS.122..387S>). The duration of total eclipse (during

which the F star is partially covered by the disk shaped companion) has increased by about 25 percent between the 1956 and 1983 eclipses. Despite this, the overall length of the total plus partial phases of eclipse - especially the time where the F star moves out from the cover of its partner - has gotten shorter!

If these trends continue, the F star will come out of eclipse (from totality) in only 1 or 2 weeks during 2011. BUT, it will still take 140 days or so to move from the beginning of the eclipse to totality next year, autumn. What is changing, and what do the variations mean? Is this binary system preparing for an energetic event?

Is the light variation due to changes in the F supergiant star's radius or temperature? Using the well-known correlation among stellar luminosity, radius and temperature, a ten percent change in Luminosity can result from a 5 percent change in Radius, or a 2.5 percent change in Temperature. At an estimated distance of 625 pc, and assuming the F supergiant star is close to the nominal 100 solar diameters appropriate for its type, then the implied angular diameter is 3 milli-arcseconds. Modern interferometers, like the Palomar Testbed Interferometer (PTI, San Diego County, CA), are capable of measuring down to fractions of one milli-arcsecond, close to that 5 percent change anticipated, and these measurements are underway. These measurements would help confirm that the F star could be causing the accelerating light changes.

What's a milli-arcsecond? Astronomers use angular measures much finer than degrees on a protractor. The arc-second is 1/3600 part of one degree, and a milli-arcsecond is 1000 times finer. A 25 cent US coin seen at a distance of 6,500 miles (10,000 km) subtends about one milli-arcsecond.

The best model for the eclipsing object makes a clear, testable prediction that is suitable for interferometry: the F supergiant star should be BIFURCATED (cut in half) by the eclipse-causing disk, if indeed it is a disk. Next generation imaging interferometers like CHARA at Mt. Wilson and MROI at Socorro, should be easily able to monitor this set of changes. If the disk is causing all of the changes in the system, that should be detected with these measurements.

Bonus points: Public participation!

The epsilon Aurigae eclipse event is being promoted as one facet of the International Year of Astronomy, IYA2009: http://astronomy2009.us/citizen_science/. It is a bright star that can be seen despite light pollution, monitored both visually and with the simplest of digital camera equipment. One goal is to better define the eclipse duration and catch the mysterious central eclipse brightening. The observing activity is intended to promote citizen science in honor of the 400th anniversary of the telescope and Galileo's applications of it – see St. Louis AAS poster #35.02, Price et al.

In summary, the bright northern star, epsilon Aurigae, is exhibiting rapid changes suggestive of dramatic events within one or two eclipse cycles, later this century. As Stencel says, "These changes offer a chance to examine the dynamics of rapidly changing stellar disks on a human timescale, and an opportunity for the public to see for themselves that stars change."

Lots of additional material available at webpage / email:

<http://www.du.edu/~rstencel/epsaur.htm> rstencel@du.edu

Forthcoming publication: Epsilon Aurigae - the Book (Hopkins and Stencel, 2008 summer).

more

References:

Disk Model, S.S. Huang 1965, Astrophysical Journal, vol. 141, p.976
Epsilon Aurigae Star System Model, Sean Carroll, et al. 1991 Ap.J. 367: 278 [invited speaker, cosmology session, Wed. #94.01]
Photometry, Jeff Hopkins, Phoenix AZ: phxjeff@hposoft.com

Artwork and illustrations, at webpage: <http://www.du.edu/~rstencil/epsaurnews.htm>

Artwork inspired by epsilon Aurigae: M.Carroll, D. Weeks, D. Egge.

Contact info for artists:

Michael Carroll - cosmicart@stock-space-images.com

Daniel Weeks - ouiques@comcast.net - 717 264 8570

D. Egge - not available.

Interferometer websites:

PTI - <http://pti.jpl.nasa.gov/index.html>

CHARA - <http://www.chara.gsu.edu/CHARA/array.html>

MROI - <http://www.mro.nmt.edu/>

CALENDAR OF ECLIPSE EVENTS:

2009 Aug 6th - predicted start of eclipse (partial phase)

2009 Dec 21st - predicted start of totality

2010 Aug 1st - predicted, mid-eclipse

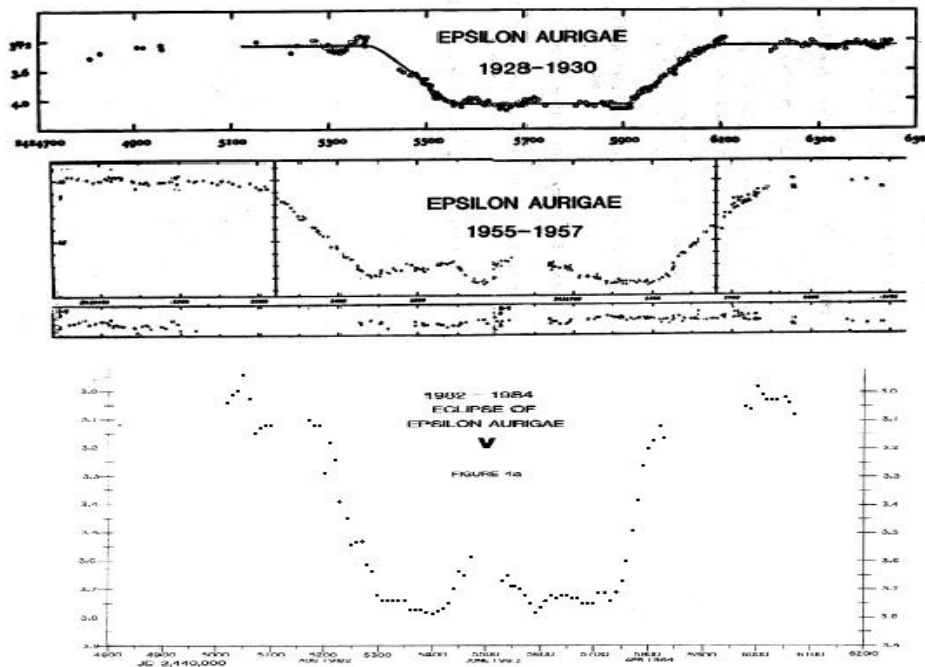
2011 March 12th - predicted end of totality

2011 May 15th - predicted end of eclipse

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2036 - next eclipse starts in autumn 2036.

Illustrations:



Published analyses of epsilon Aurigae
 Ferluga 1991:
<http://adsabs.harvard.edu/abs/1991A%26A...243..230F>

Sean Carroll et al. 1991:
<http://adsabs.harvard.edu/abs/1991ApJ...367..278C>

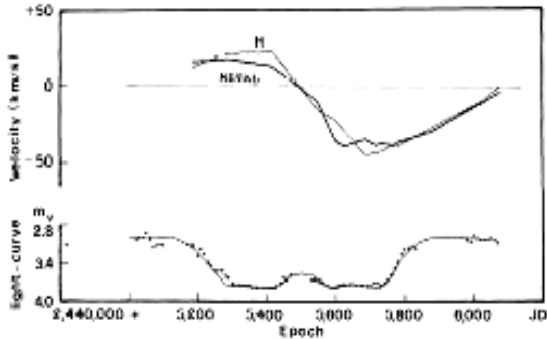
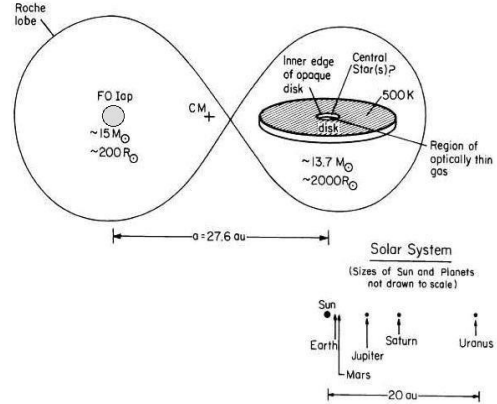
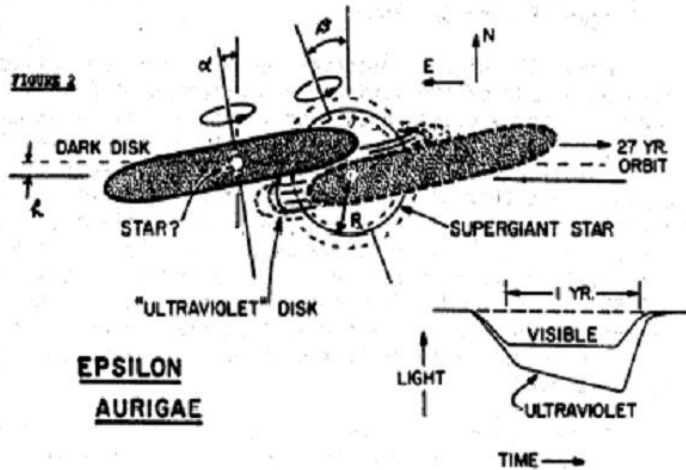


Fig. 4. The radial-velocity curve for hydrogen and metallic lines.



Models. We model the eclipse polarization in terms of limb polarization in the primary star, modulated by the passing dark cloud. For this we ignore pulsation and consider the star as spherical. See Figure 2. The star is assumed to emit polarized light concentrated strongly on the limb, due to internal scattering, with the E vector parallel to the limb. During partial eclipse this mechanism gives a non-vanishing net polarization (see e.g. Kemp et al 1983, Ap.J., 273, L85).



The asymmetrical changes in the observed polarization during the eclipse, especially the slope in the Q parameter, require that the disk must be tilted out of the orbital plane; and the orbit of the system cannot be exactly edge on, i.e. we must have $i < 90^\circ$. In Fig. 2 we indicate the non edge-on inclination by an upward displacement h , of the disk on the sky, relative to a line parallel to the orbit plane passing through the star's center. For our modelling the relevant

Kemp et al. 1985 NASA CP 2384: <http://www.du.edu/~rstencil/NASAcP2384.pdf>