TWO HUNDRED YEAR OLD MYSTERY STAR GETS CLOSER TO RESOLUTION, THANKS TO GAIA* Data Release 2

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Papers 315.01 & 315.02
Contacts: Prof. Robert Stencel, University of Denver – Astronomy &
Mr. Justus Gibson, graduate student
robert.stencel@du.edu, 1-303-871-2135

Vocabularly terms defined in appendix, below.

The visually-bright winter constellation star, epsilon Aurigae, near Capella (alpha Aurigae), is noteworthy for its **2 year long eclipses that occur only every 27 years**. First noted as a variable star in 1821, by Johann Fritsch of Germany, humanity has witnessed and documented only 8 of these eclipse cycles since (the next one starts in 2036). Study of this binary system historically had attracted the attention of noteworthy astronomers and astrophysicists such as Otto Struve, Gerald Kuiper and others, during prior eclipse events.

The **nature of the system** was in dispute for many years -- described variously as a black-hole* candidate or as the largest* star in the universe. Thanks to interferometric imaging* achieved during the 2010 eclipse, the cause of the eclipse finally was proven to be a circumstellar disk* transiting* the bright greenish F-type supergiant star.

New to the long-running research effort is the **ESA GAIA* satellite Data Release 2** that became available during April 2018. GAIA succeeded in measuring nearly a billion stars, including the tiny parallax* for the epsilon Aurigae system. GAIA DR2 reported the parallax as 2.4 +/- 0.5 milli-arcseconds*. Inverting the parallax number gives the distance in parsecs* as 500 +/- 100, which places the system significantly closer than some estimates that ran as high as 2,000 parsecs. The GAIA result turns out to be not too different from results published by classical astronomers Peter Van De Kamp (Sproul Observatory, Swarthmore PA) and Kai Strand (Yerkes), using large refractor telescopes and photographic methods during the mid-20th century. The correct parallax establishes the true distance, and importantly the true sizes and masses of stars in the system, critical for assessing the evolutionary status of the binary system.

At the **232nd meeting** of the American Astronomical Society being held in Denver Colorado, researchers Justus Gibson and Robert Stencel from the

University of Denver and their collaborators, are providing new insights based on extensive spectroscopic monitoring during the last eclipse. They used the ARCES* instrument at the 3.5 meter telescope at Apache Point Observatory (paper 315.01). These new data are complemented with new computer models using the Modules for Experiments in Stellar Astrophysics (MESA*) code (paper 315.02).

Our **ARCES*** result confirmed the existence of a mass transfer stream feeding the accretion disk in the binary star system -- indicating that mass transfer is still active, and setting a strong constraint on the age and evolutionary status of the binary. A pre-publication version of this report is available at: https://arxiv.org/pdf/1612.05287.pdf

Our **MESA*** effort builds on that constraint, and related evidence amassed during the 2010 eclipse. These paint a picture of a fairly massive binary star -- originally a 9.85 + 4.5 solar mass pair (14.35 total) and with a shorter initial period -- that evolves into a longer period, 1.2 + 10.6 solar mass result (11.8 total), after 20 million years and with 3.75 solar mass of material lost from the system. Prior to the GAIA distance result, many researchers preferred a much higher mass total model, 15 + 12 solar masses – because the primary star appears to be a supergiant, but the high mass solution is now ruled out, based on the GAIA DR2 distance estimate. The MESA calculations also reproduce an important extreme 12C/13C isotopic ratio as observed, and that is indicative of the state of internal nuclear changes in the originally more massive star, pinpointed in our MESA preferred model (Figure 1, below). This report appeared in the May 2018 issue of the Monthly Notices of the Royal Astronomical Society: http://adsabs.harvard.edu/abs/2018MNRAS.476.5026G and https://arxiv.org/pdf/1803.06392.pdf

The **overall significance** of this work also is, in part, its application to the wider class of interacting binary stars known as Algols* -- an evolutionary phase undergone by a large number of binary stars in our galaxy. Details of the mass transfer process have been debated for years, and MESA models like the one for epsilon Aurigae provide a path-finding exploration of the physics and parameters in play.

Also significant is how this brightest prototype of an emerging class of "disk-eclipsed" binaries, being discovered in sky surveys, can provide high signal to noise reconnaissance for the fainter examples of similar phenomena being recognized elsewhere in our galaxy and in the Magellanic Clouds. Further studies are planned.

Vocabulary:

GAIA – the European Space Agency astrometry satellite: http://sci.esa.int/gaia/

Algols - interacting binary stars involving a main sequence star and an evolved star companion.

ARCES: a high-resolution optical spectrometer at Apache Point Observatory, https://www.apo.nmsu.edu/arc35m/Instruments/ARCES/

Black holes – baryonic mass concentrated within a Schwarzshild radius.

Circumstellar disk - a gas and dust short cylindrical structure surrounding some stars, either during star formation, or as a result of mass transfer in a binary.

Interferometric imaging - a multi-telescope method of achieving super-resolution.

MESA – Modules for Experiments in Stellar Astrophysics, https://arxiv.org/pdf/1009.1622.pdf
Milli-arcseconds = 0.001 arcsec, where each arcsec = 1/60 arcmin and each arcmin = 1/60 degree of angle.

Parsecs – an astronomical distance unit equivalent to 3.26 light years.

Transiting - eclipsing, as in exoplanet transits.

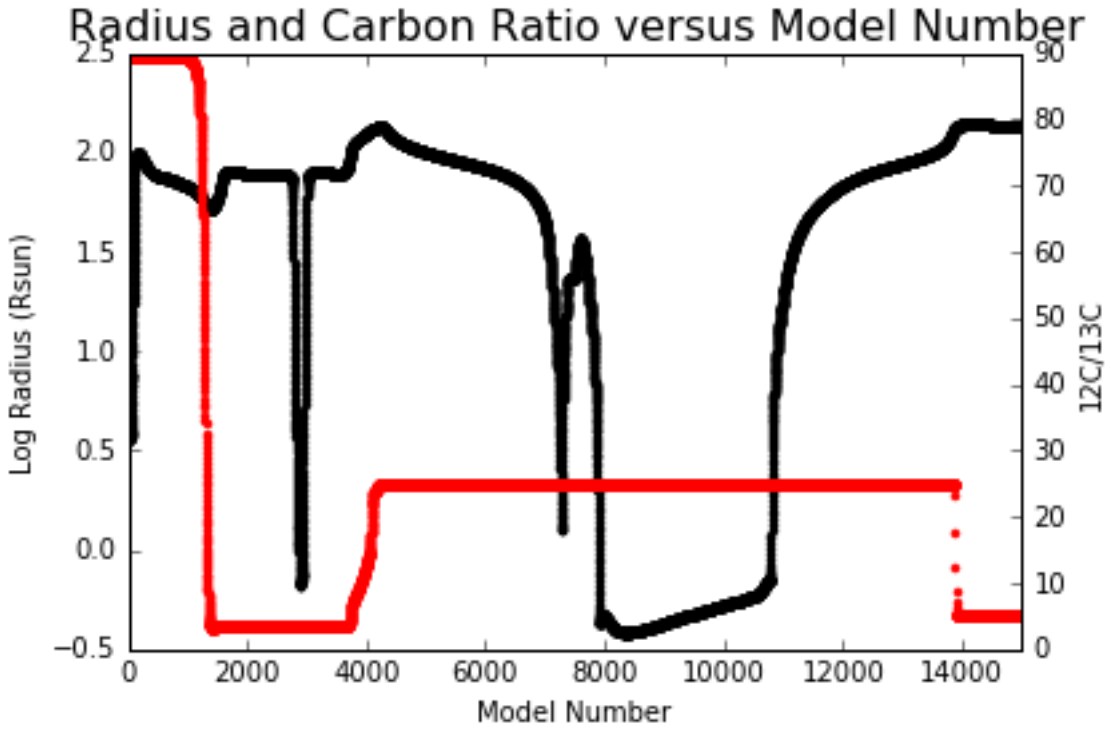

Figure from Gibson and Stencel 2018 MNRAS* showing time variation of donor star radius and isotopic carbon ratio. Intervals with large radius (100 solar) and low 12C/13C = 5 best match the currently observed conditions in epsilon Aurigae binary. * https://arxiv.org/pdf/1803.06392.pdf