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DISTANCE, LUMINOSITY AND EVOLUTIONARY STATUS OF ϵ AURIGAE (F0IAEP) FROM GAIA DR2 PARALLAX

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Abstract

From Gaia DR2 parallax of ϵ Aurigae the distance, M_v, M_{bol}, and log($L_*/L_\odot$sun) are found to be 445 parsecs, −6.5 mag, −6.5 mag, and 4.5 respectively. These results clearly indicate that ϵ Aurigae (F0Iae) is post-AGB star. The progenitor of ϵ Aurigae is most likely an intermediate mass star of 4 to 5 solar masses or the progenitor may be a star which is lower limit of a super-AGB star.

1 Introduction

ϵ Aurigae (HD 31964) is an eclipsing binary system with an orbital period of 27.1 years. The primary minimum in the light curve is caused by a large, disk-shaped invisible companion. There is no secondary minimum in the light curve. The primary eclipse is total with a depth of 0.8 magnitudes and duration of the totality phase is 330 days. The primary eclipse depth is independent of the wavelength over a wide wavelength range. It is a single-lined spectroscopic binary (Stefanik et al. 2010). ϵ Aurigae has been studied for the past 100 years or more; even then the masses of the components, the nature and origin of the disk-shaped secondary and the evolutionary stage of the components are still under debate. There are two models now for ϵ Aurigae, a F0Iaep star. A high-mass star with a mass in the range of 15 or 20 solar masses to 50 solar masses and $M_v = -9$ to -10 mag, or a post-AGB star whose progenitor was a low or intermediate mass star.

The proposed models of the disk-shaped secondary range from a swarm of meteorites to a black hole (Ludendorff 1924, Cameron 1971). Huang (1965) proposed that the secondary is an opaque disk of cool material seen edge on. The results of the 1955 eclipse, earlier literature and models of ϵ Aurigae were reviewed by Wright (1970), Kopal (1971), Wilson (1971), Gyldenkerne (1970), Sahade and Wood (1978).

Many new results and facts have emerged from detailed spectroscopic, photometric and interferometric observations carried out from far UV to far IR during the 1982–1984 and 2009–2011 eclipses of ϵ Aurigae (see Stencel, 2012, and references therein, and Gibson & Stencel, 2018). Eggleton & Pringle (1985) were the first ones to propose that ϵ Aurigae is in post-ABG stage of evolution.

One of the major problems that prevented the understanding of the evolutionary stage of ϵ Aurigae was its distance remained unknown until the recent Gaia mission. Several researchers in the past have used distance of 1 Kpc to 1.5 kpc resulting in high luminosity and high mass for ϵ Aurigae. Recently from the Gaia DR2 we have relatively accurate parallax of ϵ Aurigae. In this paper we report the results based on the Gaia DR2 parallax of ϵ Aurigae and derive its luminosity and discuss its evolutionary status.

2 Distance, Luminosity and Evolutionary Status

Gaia DR2 parallax of ϵ Aurigae is found to be 2.4144 ± 0.5119 mas (Gaia Collaboration, 2018). The distance of ϵ Aurigae from its parallax is 414 parsecs, but according to Bailer-Jones et al. (2018), going from a Gaia parallax to distance is a non-trivial issue and cannot be obtained by simply inverting the parallax. In the following we adopt the distance given by the inference procedure developed by Bailer-Jones et al. (2018): 444.893 ± 94.326 parsecs. Using this distance and observed V magnitude ($V = 2.99$ mag) and observed $B-V$ color ($B-V = 0.54$ mag), the intrinsic color of a F0Ia star is $(B-V)_0 = 0.17$ mag, and hence the observed $E(B-V)$ is 0.38 mag (which we adopted here). More details of derived $E(B-V)$ values can be found in the papers of Hack & Selvelli (1979), Castelli (1978), Ake & Simon (1984), Stencel (2012), all these values agree with our adopted $E(B-V)$ value. Using the above mentioned data we find $\mathrm{M}_v = -6.467 \pm 0.350$ mag.

For F0Ia stars the bolometric corrections are almost zero. Therefore we adopt $\mathrm{M}_v = \mathrm{M}_{\mathrm{bol}} = -6.467 \pm 0.350$ mag. Hence the luminosity of ϵ Aurigae is $\log(\mathrm{L}_*/\mathrm{L}_\odot) = 4.5 \pm 0.35$.

To understand the evolutionary status of ϵ Aurigae we have used the post-AGB evolutionary models from the paper of Miller-Bertolami (2016) for initial masses 0.8 solar masses to 4 solar masses with solar metallicity. The location of ϵ Aurigae in the HR diagram of Miller-Bertolami indicates that it is a post-AGB star and the progenitor initial mass is about 4 solar masses to 5 solar masses. ϵ Aurigae seems to have evolved from a intermediate mass star or from a super-AGB star.

3 Discussion and Conclusions

Mass-transfer stream with rare-earth elements from ϵ Aurigae (Griffin & Stencel 2013) and low $^{12}\mathrm{C}/^{13}\mathrm{C}$ ratio = 5 (Stencel et al. 2015) observed during the third contact of the eclipse also confirms that ϵ Aurigae is a post-AGB star. Using the MESA code, Gibson & Stencel (2018) conclude that ϵ Aurigae is a post-RGB/ pre-AGB star. Based on the Gaia DR2 data we conclude that the distance to ϵ Aurigae is 445 parsecs. Its absolute brightness is $\mathrm{M}_v = -6.5$ mag and it is a post-AGB star. It seems to have evolved from a intermediate mass star of 4 to 5 solar masses or the progenitor star may be on the lower limit of super-AGB stars (Hidalgo et al. 2018).

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