NEAR-INFRARED OBSERVATIONS OF THE PECULIAR BINARY SYSTEM EPSILON AURIGAE

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Abstract. Near-infrared photometric and low-resolution spectroscopic observations of ε Aurigae at two phases during the current eclipse are presented. The eclipse depths are found to be wavelength-independent in the infrared right up to 2.5 μm. There is no infrared excess at wavelengths shorter than 2.5 μm. The light absorbing particles in the eclipsing body must be larger than 10 μm in size.

1. Introduction

ε Aurigae (BD + 43° 1166) is an eclipsing binary system with an orbital period of 27.1 yr. The light curve is of the Algol type, but displays only one minimum that is about 0.82 mag. deep in the visible. The duration of the entire eclipse is 714 d while the totality lasts for 330 d. Extensive observations of the system in the visible were made during the eclipses of 1928–30 and 1955–57. The basic observed facts regarding ε Aurigae have been well summarized and discussed by Kopal (1971). It is a single-lined spectroscopic binary whose primary component is of the spectral type F2I with an effective temperature of 7400 K. This spectrum is present at all phases including the phase of minimum light. There is no secondary minimum and the eclipse depths during the observed primary eclipse are independent of wavelength. The absence of a secondary minimum indicates that the secondary (the occulting) component has a very low luminosity in the visible. The observed eclipse depth (∼ 0.82 mag.) and the relative durations of totality and the entire eclipse cannot be reproduced by any normal eclipsing star (see, e.g., Kopal, 1971). If the eclipsing object is a semi-transparent body it must be composed of particles whose dimensions are much larger than the wavelength of visible light because the eclipse depths are independent of wavelength in the visible. For these reasons, models have been constructed for ε Aurigae where the eclipse of the F2I star is caused by a flat disc of dust and gas that surrounds the invisible secondary (e.g., Handbury and Williams, 1976; Huang, 1965; Kopal, 1954).

Although the secondary component in ε Aurigae does not show up in the visible, it might reveal its presence at longer wavelengths in the infrared. Infrared photometry of ε Aurigae made by Mitchell (1964) and Woolf (1973) at orbital phases well out of the eclipse show that the secondary component does indeed contribute appreciable flux of radiation at wavelengths longward of ∼ 5 μm. The effective temperature of this component is ∼ 500 K.

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2. The Current Eclipse of Epsilon Aurigae, 1982–84

The current eclipse of ε Aurigae began some time in late March 1982 and is expected to last till around early March 1984. The second contact occurred in early December 1982 (Ake and Simon, 1983, *IAU Circ.*, No. 3763; Japan Amateur Photoelectric Observers Association, 1983, *Inf. Bull. Var. Stars*, No. 2371). The eclipse depth in the visible is about 0.86 mag. and again independent of wavelength in the visible. During the present totality $V = 3.82$ and $B - V \simeq 0.54$ (*Inf. Bull. Var. Stars*, No. 2371) compared with the pre-eclipse values $V = 2.96$ and $B - V = 0.54$ (Johnson *et al.*, 1966). The present eclipse has provided us the first opportunity to study the secondary component of ε Aurigae in infrared during eclipse. During this phase the infrared continuum of the primary is expected to be suppressed by about a factor of two due to occultation; and, hence, detection of the infrared emission of the occulting body even at shorter infrared wavelengths ($\lambda < 5$ μm) might be easier. The wavelength-dependence of the eclipse depths in the infrared is of considerable importance. This would help us find whether the eclipsing matter becomes more transparent at longer wavelengths and thus put some limits on the particle sizes. With this in view we have carried out near-infrared broad band photometry of ε Aurigae at two phases. One during the totality

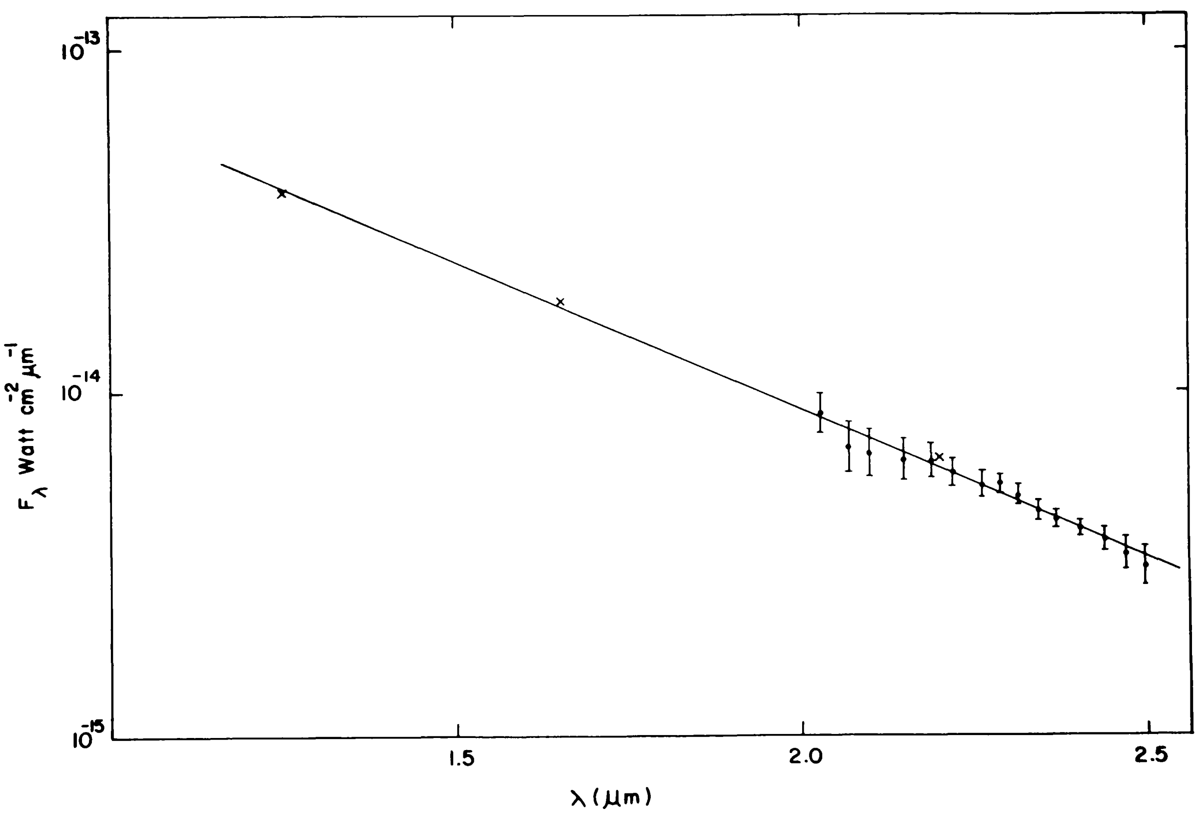

Fig. 1. Near-infrared spectrum of ε Aurigae on 26 November, 1983. J(1.25 μm), H(1.65 μm), K(2.2 μm) photometric measurements are represented by ×. The continuous line is a 7400 K black-body spectrum fit to the observations.

(7 February, 1983) and the other during egress (26 November, 1983). At the latter phase we were able to secure a low resolution infrared spectrum in the range 2–2.5 μm in addition to the photometric measurements at J(1.25 μm), H(1.65 μm), and K(2.2 μm).

3. The Infrared Observations

The observations were obtained with the 104 cm telescope at the U.P. State Observatory, Nainital, India. A liquid nitrogen cooled In Sb photometer with a circular variable filter wheel was used. The spectral resolution in the range 2–2.5 μm was 1.5%. Table I gives the photometric magnitudes determined and Figure 1 shows the spectrum. In Figure 1 the points (marked as ×) corresponding to the photometric magnitudes measured on 26 November, 1983 are also shown. For comparison in Table I the pre-eclipse J and K magnitudes for ε Aurigae by Johnson *et al.* (1966) are also given.

TABLE I

Infrared photometry of ε Aurigae

Date	J	H	K	$(J - K)$
7 Feb., 1983	2.45	2.22	2.11	0.34
26 Nov., 1983	2.35	2.09	2.01	0.34
Johnson *et al.* (1966)	1.82	–	1.48	0.34

4. Discussion

It is clear from Table I that during the current eclipse ε Aurigae has become fainter in the near infrared too. On 7 February, 1983 the system was 0.63 mag. fainter in J as well as K compared to its pre-eclipse brightness. By 26 November, 1983 it had brightned up by 0.1 mag. as expected during the egress. Unfortunately, we do not have any simultaneous photometric measurements in the visible to compare with.

The point of interest here is that the $(J - K)$ color of ε Aurigae is independent of the phase and is 0.34 as seen from Table I. Our measurements thus suggest that the eclipse depths in the infrared J, H, K photometric bands are independent of wavelength. This fact is supported in greater detail by the spectrum presented in Figure 1. In Figure 1 we show that the infrared spectrum of ε Aurigae on 26 November, 1983 when the eclipse depth was 0.53 mag. is well fit (drawn as the continuous line) by a blackbody of effective temperature 7400 K. This corresponds also to the spectrum of ε Aurigae well out of eclipse. We, thus, conclude that the eclipse depths for ε Aurigae are independent of wavelength at least up to 2.5 μm. If the radiation absorbing grains are characterized by radius a, refractive index m, then $4\pi a(m - 1)/\lambda \gtrsim 10$ for the extinction to become wavelength independent up to wavelength λ. For $m \simeq 1.5$, $\lambda > 2.5$ μm we have $a \gg 4$ μm.

Thus, the dust particles are likely to be larger than 10 μm in size. We also conclude that there is no infrared excess radiation at wavelengths shorter compared to 2.5 μm. Our observations are consistent with the measurements of Backman *et al.* (1983) who find excess radiation only at 10 and 20 μm attributable to the secondary component in ε Aurigae.

5. Conclusions

The near-infrared spectrophotometric observations discussed in this paper show that the eclipse depths in ε Aurigae are wavelength independent up to wavelengths as long as 2.5 μm. The colors are phase independent and the spectrum in the near infrared is well fit by a blackbody of effective temperature 7400 K. There is no excess radiation contributed by the secondary component at wavelengths shorter than 2.5 μm. The grains constituting the eclipsing component are larger than about 10 μm in size.

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