A SPECTROPHOTOMETRIC STUDY OF GG CASSIOPEIAE

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Abstract. The continuum energy distributions of a totally eclipsing binary system GG Cas at phases $0\overset{p}{.}903$ and $0\overset{p}{.}003$ in the wavelength range $\lambda\lambda$3200–7600 Å have been presented and discussed. The flux of continuum of the secondary star seems to dominate longward of λ4500 Å. The spectral types of the systemic components are found to be as B4 + K0.

1. Introduction

The eclipsing binary system GG Cas (BD + 55°274) was discovered to be an Algol-type eclipsing variable by Leiner (1944). Herbig (1952), Popper (1956), and Azimov (1963) presented the spectral type of the system. Orbital elements of the system have been derived by Srivastava and Kandpal (1970) and Chaubey (1984). Recently, Srivastava (1987) has studied the period variability of the system.

Popper (1956) observed the system GG Cas spectroscopically and reported that the spectrum of GG Cas is composite and that the lines of a late type star are dominating the spectrum longward of λ4100 Å. He estimated the spectral type of the hot star to be of type B5–B8 and cool star being about K0III. This totally eclipsing binary system GG Cas ($P = 3\overset{d}{.}759$, $d \simeq 2^h$) was included in our spectrophotometric observing programme in 1983, to study the continuum energy distributions of the component stars of eclipsing binary system. The purpose of this paper is to present the spectrophotometric observations of the system GG Cas and to discuss the results.

2. Observations

The spectrophotometric observations of GG Cas were taken in the wavelength range $\lambda\lambda$3200–7600 Å on 20 November, 1983, with the 104-cm telescope of Uttar Pradesh State Observatory, Nainital. The Hilger and Watts spectrum scanner was used at the Cassegrain focus ($f/13$) of the reflector for obtaining the spectral scans. An exit slit of 50 Å width was used. The standard d.c. techniques were used for detecting and recording the signal. A total of 18 scans (4 scans at outside the eclipse phases, 12 during the partial primary eclipse, and 2 within the totality of the primary minimum light) have been taken. We have also observed 6 photometric standard stars as listed in Table I, for the comperison purpose.

Along with these, the spectrophotometric standard star ξ^2 Cet was observed many times during the same night for deriving the extinction coefficients and converting the observations into standard monochromatic magnitudes. The absolute calibration of ξ^2 Cet, given by Taylor (1984) was adopted. The standard deviations of the observa-

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TABLE I

A list of stars observed for the comparison

HD	HR	Star name	Spectral type	m_v
9270	437	η Psc	G8III	3.62
23324	1144	18 Tau	B8V	5.65
46271	2382	12 Mon	K0III	5.83
69267	3249	β Cnc	K4III	3.53
184171	7426	8 Cyg	B3IV	4.75
217782	8766	2 And	A3V	5.04

tions does not exceed $\pm 0\overset{m}{.}03$ in the whole wavelength region. The observed standard normalised magnitudes of GG Cas at phases $0\overset{p}{.}903$ and $0\overset{p}{.}003$ against wavelengths are given, respectively, in Figures 1 and 2. Phases have been computed with the ephemeris:

$$M(E)\ \text{J.D. (Hel.)} = 2\,440\,209.2202 + 3\overset{d}{.}758719E\,. \tag{1}$$

In the above, the epoch is the time of primary minimum light observed by Srivastava and Kandpal (1970) and the period is computed by us.

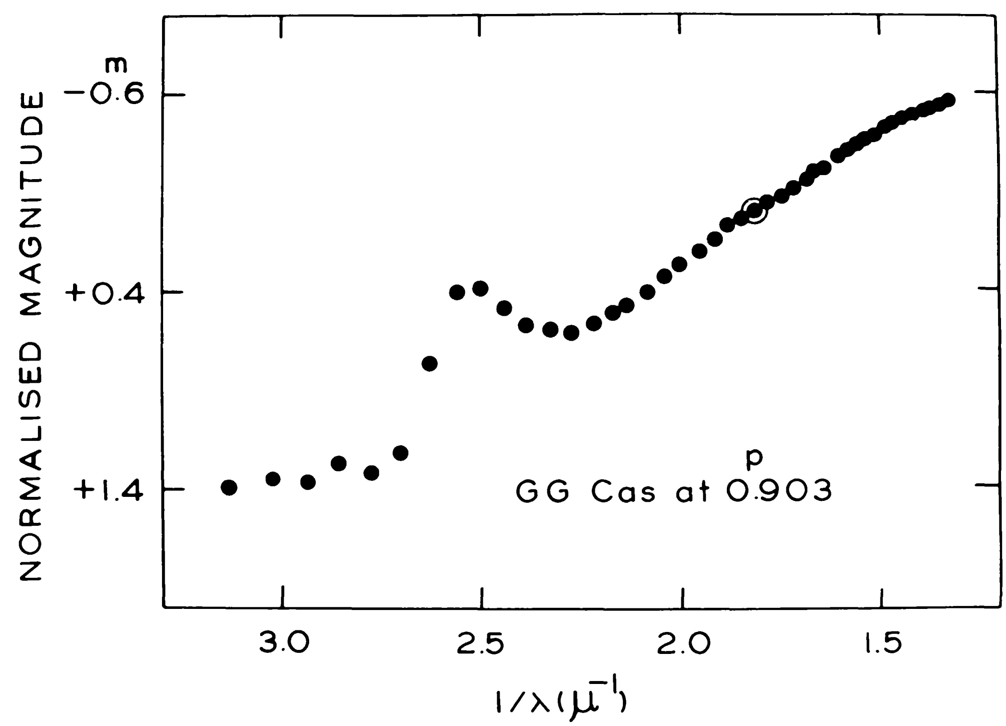

Fig. 1. Observed continuum of GG Cas (filled circles) at $0\overset{p}{.}903$. The normalisation has been done at λ5500 Å denoted by filled circle surrounded by an open circle.

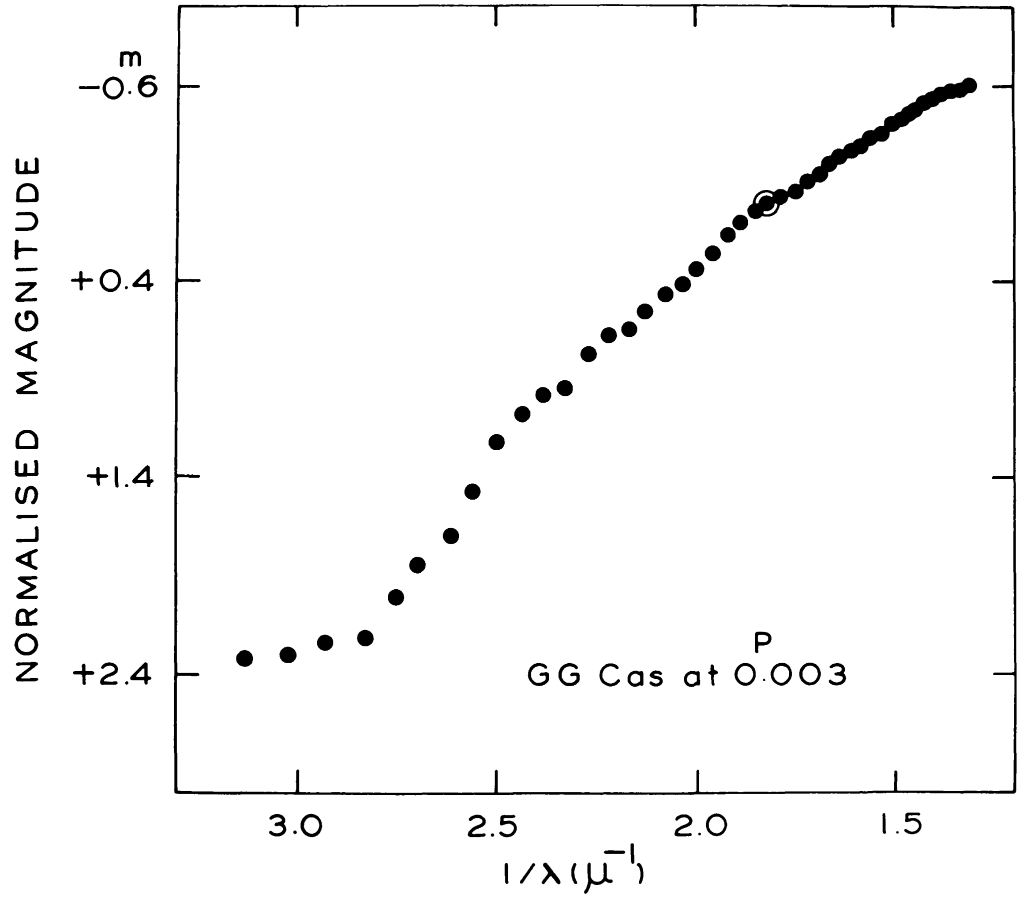

Fig. 2. Observed continuum of GG Cas at $0^P.003$. Notations are the same as for Figure 1.

3. Flux Distribution of the Primary Star

The spectrum of the primary star of the eclipsing binary system GG Cas may be constructed from the intensity tracings, by subtracting the intensity of the spectral scan of the secondary star as observed at the totality from the intensity of the composite spectral scan of the system as observed outside the eclipse. In order to get the continuum flux distribution of the primary star, the observed magnitudes of both the spectrum (Figures 1 and 2), at the interval of 10 nm, were converted into flux (Hayes *et al.*, 1975) with the aid of the equation

$$m_\lambda = -2.5 \log F_\lambda + 21.17 , \tag{2}$$

where m_λ and F_λ are, respectively, the monochromatic magnitude and flux at wavelength λ.

As in practice, further in all our calculations, we need normalized monochromatic magnitude, therefore, the extracted monochromatic fluxes of the primary star were converted into normalized magnitudes with the help of the equation

$$Nm_\lambda = -2.5 \log(F_\lambda / F_{550}) , \tag{3}$$

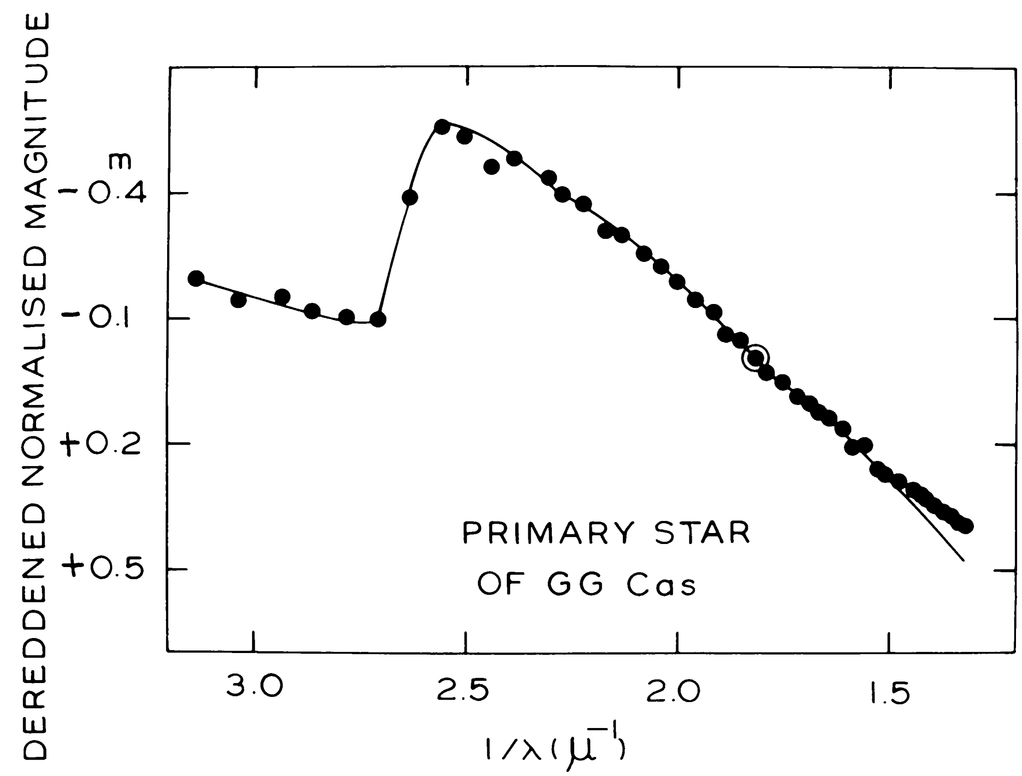

Fig. 3. Comparison of the continuum of primary star in GG Cas (dots) with the Kurucz (1979) model for $T_{\rm eff}$ = 16 000 K and log g = 4.0 (continuous curve).

where Nm_λ is the normalized magnitude at wavelength λ and F_{550} is the monochromatic flux at wavelength λ550 nm. In this way, the continuum flux distribution curve obtained for the primary star is given in Figure 3.

It is clear from Figure 3 that the primary star in GG Cas is an early-type star. To determine its spectral class, the flux distribution (Figure 3) was matched to the flux distribution of the early type standard stars as listed in Table I. It is found that the continuum of the primary star matches with 8 Cyg (B3) and differs very much from 18 Tau and 2 And. The effective temperature of the primary star of GG Cas can be determined by using the synthetic spectra constructed by Kurucz (1979).

Kurucz (1979) computed models assuming plane-parallel geometry, hydrostatic equilibrium, local thermodynamical equilibrium, assuming no molecular formation in the equation of state and radiative plus convective energy transports. Line blanketing was included through a statistical distribution function, representation of the opacity of almost 1 000 000 atomic lines. We have already used Kurucz models for single stars of early spectral types (Singh and Chaubey, 1987).

Kurucz's grid of model atmosphere with solar abundances and microturbulence velocity of 2 km s^{-1} were superimposed on the observed spectra (Figure 3) for deriving the effective temperature. It is found that the flux distribution data of primary star is well matched with the model atmosphere having $T_{\rm eff}$ = 16 000 K and log g = 4.0 (i.e., B4V). The model (solid continuous curve) fitted with the observations is also shown in Figure 3.

4. Flux Distribution of the Secondary Star

Two spectrum scans of GG Cas, observed during the time of total primary eclipse, represent the spectrum of the eclipsing secondary star. These spectrum scans enable us to classify the secondary star of GG Cas by matching its flux distribution to those of late-type giant stars and also to derive the effective temperature by matching the continuum energy distribution from the model atmosphere. For this purpose, we have computed the mean flux values for these two spectrum scans given in Figure 2.

In order to apply the reddening correction, we have estimated the colour excess using the photometric data and light curves of GG Cas taken from Popper (1956) and Srivastava (1976). From the observed colour indices outside the primary eclipse and within the primary eclipse, we have determined the colour indices of the primary star. A plot of these colour indices on the colour-colour diagram suggests that primary star is a reddened, $E(B - V) = 0^{m}.18$, B4 Main-Sequence star. This spectral type is in good agreement with our results for the primary star, obtained in Section 3.

Thus we have corrected the observed continuum of the secondary star in GG Cas for reddening by taking the value of $E(B - V) = 0^{m}.18$. The reddening at the visual

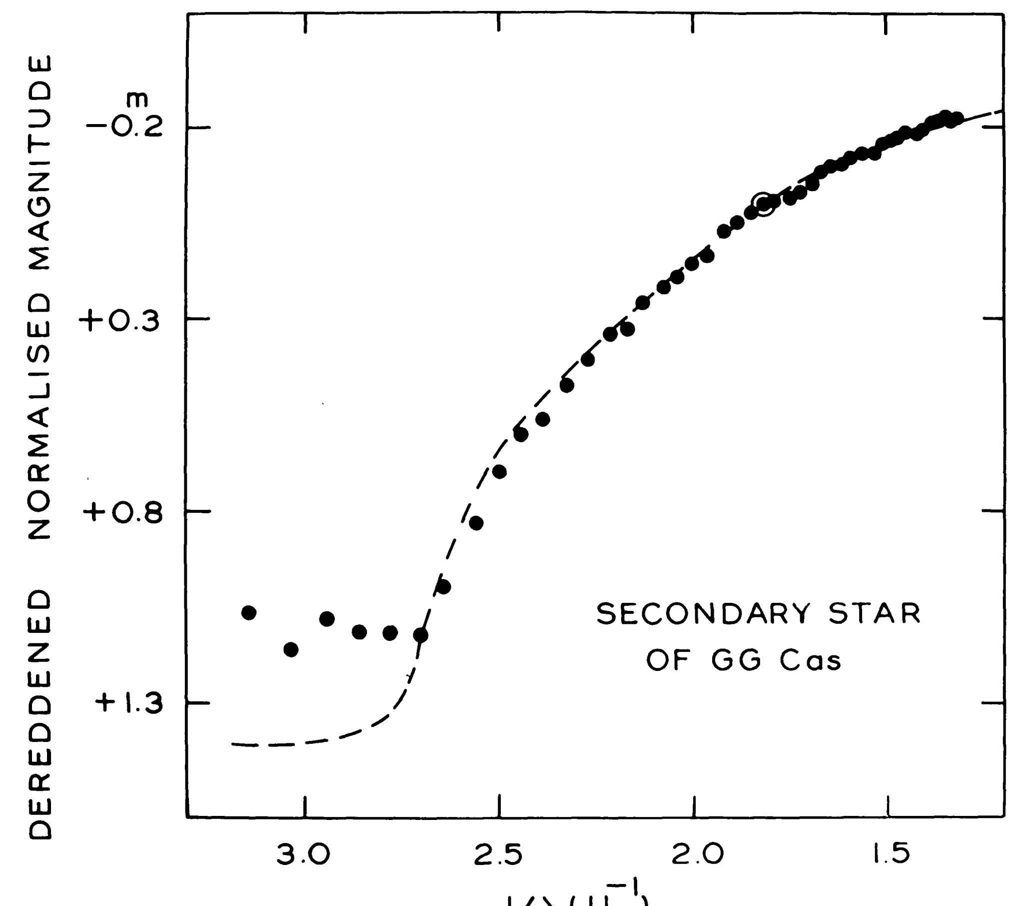

Fig. 4. Comparison of the continuum of secondary star in GG Cas (dots) with the continuum of 12 Mon (dashed curve).

magnitude (A_V) was determined by adopting the mean value of total-to-selective extinction $R = 3.25$ (Moffat and Schmidt-Kaler, 1976). The reddening corrections at different wavelengths were worked out by using the value of A_V and extrapolated reddening law by Lucke (1980). The de-reddened magnitudes normalized to wavelength $\lambda 550$ nm against wavelengths are shown in Figure 4.

It is clear from Figure 4 that the continuum flux distribution of the secondary star indicates an effective temperature below the lower limit in the Kurucz's grid of model atmospheres. Therefore, we are unable to derive the effective temperature of the secondary star in GG Cas.

In order to determine the spectral type of the secondary star in GG Cas, we have compared its observed de-reddened normalized monochromatic fluxes with the observed de-reddened normalized monochromatic fluxes of three photometric standard late type giant stars as listed in Table I. It is found that flux distribution of the continuum of the secondary star matches with the flux distribution of the continuum of photometric standard star 12 Mon (K0III) in the wavelength range $\lambda 390$ to $\lambda 760$ nm (Figure 4). Thus we have assigned the spectral type of secondary star as K0. This finding based on continuum flux distribution data, is in good agreement with the spectral type K0 given by Popper (1956) for the secondary star in GG Cas obtained from the spectra.

It is also noticed from Figure 4 that the fluxes of the secondary star in GG Cas for $\lambda < 390$ nm are higher than the 12 Mon. This may be, in our opinion, due to the additional radiation which originates in the uneclipsed part of the optically thin hydrogen cloud around the hotter primary star. It must also be kept in mind that the total flux as well as monochromatic fluxes of the Roche-lobe filling secondary star should vary with phase, the star being least luminous at $0\overset{P}{.}0$.

5. Conclusions

From the above, we find that GG Cas is an evolved eclipsing binary system in which a cooler K0-type star eclipses a hotter B4-type star during the primary minimum. The flux of the continuum of the secondary star is dominating at longer wavelengths, i.e., $\lambda > 450$ nm. The presence of circumstellar material around the hotter primary star is also noted, since the fluxes of the secondary star in GG Cas for $\lambda < 390$ nm are higher than the 12 Mon.

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