EG Cephei

Tri Le, San Diego Mesa College
Advisor: Dr. Ron Angione, San Diego State University

Several topics on EG Cephei are discussed. Spectral type A4 of the system and an approximate temperature of the brighter star were determined using the equivalent width of Hα feature. 5 new times of minima are revealed. They fit well in with other published data. The shape of O-C curve can be placed under more than one interpretation. A quadratic fit should lead to mass transfer activity of the system. In another possibility, a third body may be responsible for a sinusoidal fit. Two modes of Wilson Devinney are examined in order to generate a model of the light curve.

Introduction

The EG Cephei binary system was discovered by Schohmeier in 1958. This is an eclipsing binary system with a period of 0.5446 days; however, studies have indicated a period change of the system. Many researches have focused on predicting and explaining this period instability. In this summer project I was able to check the spectral type, investigate the period change and try to model the light curve.

Observations and Reduction

Angione and Etzel took the CCD spectra of EG Cephei in May 2004 on the 12-inch telescope at Mount Laguna Observatory. Raw pictures were fixed bad pixels, adjusted bias level and subtracted flat images. The next step was specifying aperture for each picture and identify spectral lines from a comparison source, which in this case is neon. Finally, applying wavelength calibration and continuum function helps to level out the spectra. The result was spectra of Hα feature.

5 new times of minima were calculated using Kwee-Van Woerden method (Cooban 1967). We collected all the published times of minima for EG-Cep since Schohmeier. A large portion of this list was gathered in 1998 paper *On the orbital changes of EG Cep* by Chochol (1998). We added more recent minima from other sources included Wunder (1992), Agerer and Hubscher (2001), Pribulla (2002), Nelson (2005), Demircan (2003), and Bakis (2003). These times of minimum then ran through a small FORTRAN program named Period to achieve the O-C table. The O-C curve was plotted using xmgrace.

Spectral analysis

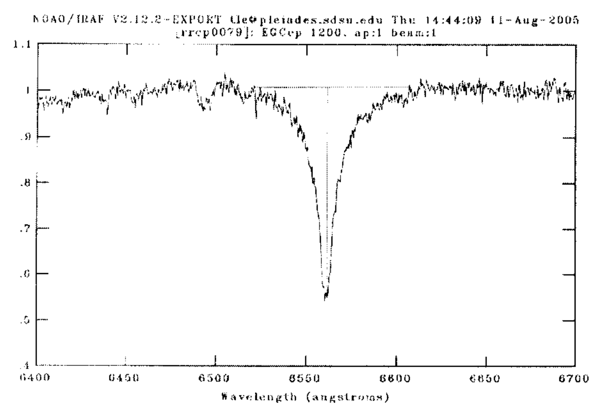

Figure 1

The equivalent width of the Hα feature is 8.8 which, according to Jaschek, indicates an A4 spectral type. The temperature is also determined to be about 8500 Kevin. There is no evidence of mass exchange.

Period investigation

5 times of minima that I calculated:

2439004.7837	2438137.6721	2439290.7096	2439292.8882	2439297.7895

Strohmeier first suggestion for the ephemeris was: $Min = JD\_hel\ 2426929.485 + 0.5446202 \times E$

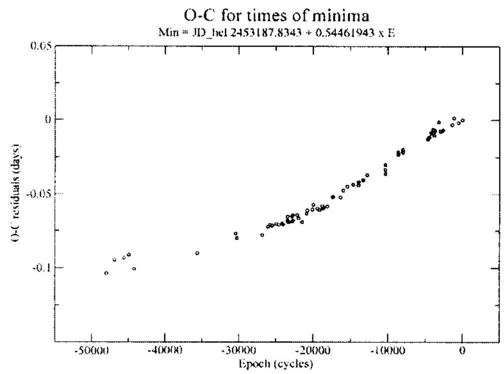

Figure 2

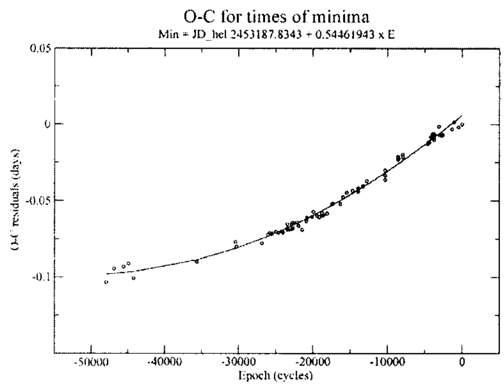

Figure 3

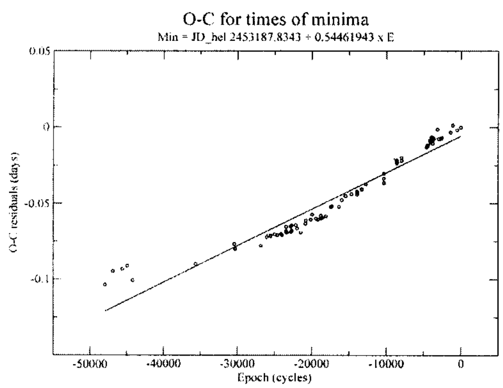

Figure 4

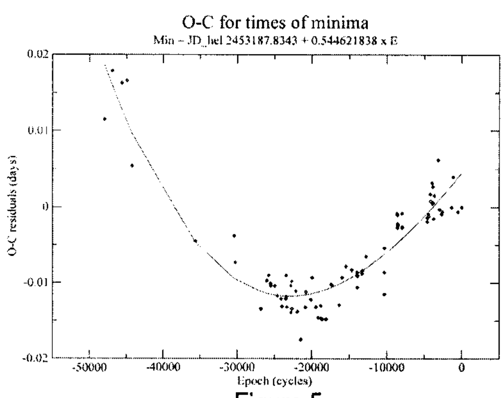

Figure 5

From the times of minima collected, the O-C curve was obtained using the period from Chochol's period (1998)
$Min = JD\_hel\ 2453187.8343 + 0.54461943 \times E$
(These numbers represent the newest times of minima and the most recently published period)

- O = time of observed minimum light
- C = calculated time of minimum light
- JD_0 = time of minimum light at E=0
- P_{est} = estimated period
- $P_{(E)}$ = true period of system (possibly a function of E (time))

$$O = JD_0 + P_{(E)}E$$
$$C = JD_0 + P_{est}E$$
$$O - C = \left[P_{(E)} - P_{est}\right]E$$

Assume that O-C residuals can be fit by a parabola:

$$O - C = aE^2 + bE + c$$

Then

$$P_{(E)}E + P_{est}E = aE^2 + bE + c$$
$$\frac{dP_{(E)}}{dE}E + \left[P_{(E)} - P_{est}\right] = 2aE + b$$

Hence

$$\frac{dP_{(E)}}{dE} = 2a \quad \text{and} \quad P_{(E)} - P_{est} = b$$

As seen in the equation, derivative of real period is relative to a. In the case that O-C curve is a linear fit then a=0 and b is the difference between the real period and the estimated period (Bradstreet). There are two possibilities of fitting curves on the plot. The first one is a parabola and the second one is a straight line. Since we were not sure if the period we used was the good one, we decided first to use the linear fit in order to make a correction. The equation was: $O - C = 2.40760 \times 10^{-6} E - 5.57783 \times 10^{-3}$. Thus 2.40760×10^{-6} was the period correction factor. The new period obtained was 0.544621838 days. Fitting a new parabola curve to the re-plotted data produces

$$O - C = 3.9717 \times 10^{-11} E^2 + 1.675 \times 10^{-6} E + 6.0854 \times 10^{-3}$$

It implies a constant increase of the period therefore the new ephemeris is

$$Min = JD\_hel\ 2453187.8343 + 0.54461943 \times E + 3.9717 \times 10^{-11} E^2$$

Mass transfer from the less massive star to the more massive one might be an explanation for this period increase.

However, there are hypotheses on the period change that should be considered.

Chochol proposed there are two linear fits in Figure 5 caused by a sudden change in period during 1972. The explanation is still the mass transfer from the less massive star to the more massive one. Also from Figure 4, removing the linear line would yield a sinusoidal fit. In that case, the light time effect created by a third body would be responsible for a periodic change of 70 years.

Light curve model

The Wilson-Devinney method was used to model the light curve. It is done by using 2 modes:

Mode 2 Detached system	Star1	Star2
Mass/Solar Mass	1.47	0.70
Radius/Rsun	1.57	1.15
Temperature	8500K	5650K
Albedo	1.000	0.500
Potential gravity	2.8919	2.8380
Relative brightness	0.9028	0.0971
Limb darkening	0.491	0.605
Mass ratio	0.4800	

Mode 5 Semi-detached system	Star1	Star2
Mass/Solar Mass	1.47	0.70
Radius/Rsun	1.57	1.15
Temperature	8500K	5650K
Albedo	1.000	0.500
Potential gravity	2.8919	2.8380
Relative brightness	0.9028	0.0971
Limb darkening	0.491	0.605
Mass ratio	0.4800	

In the detached system model, each star stays within its own Roche Lobe, the gravitational equipotential surface. In semi-detached system, however, the fainter component is expanded to fulfill its Roche Lobe. The model of the light curve is shown in Figure 6

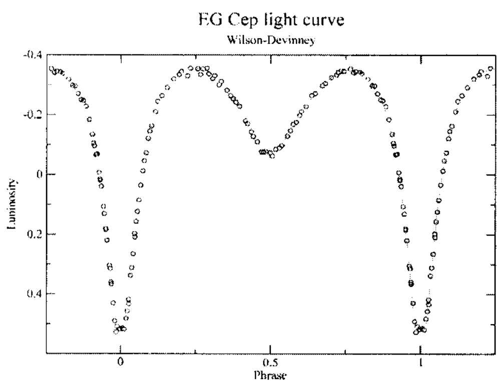

Figure 6

The graphs below are the O-C plots for the light curve. Figure 7 illustrates a basic model of the system while Figure 8 included a spot model similar to a sunspot on the fainter star. The result, as compared in two figures, has a much better appearance for the O-C residuals.

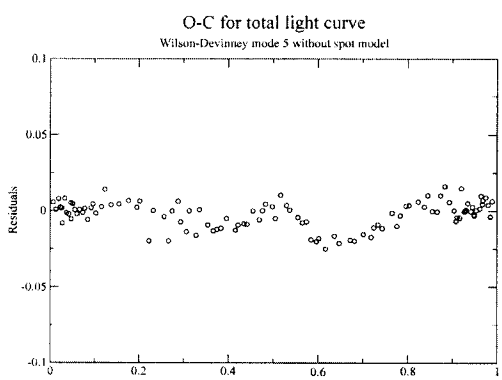

Figure 7

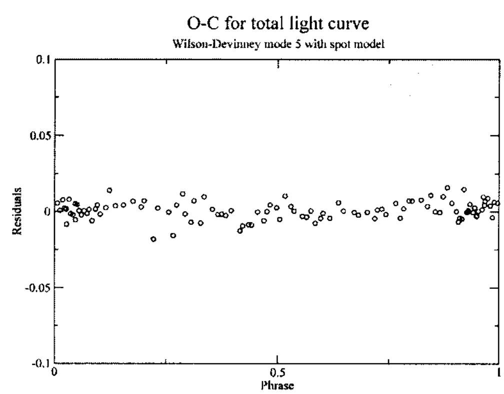

Figure 8

Conclusions

Spectral type was determined as A4. Due to the short history of EG Cep study, the period instability still remains inconclusive. It requires time, properly a few more decades, in order to draw a final conclusion of which hypothesis is right. Also, more work has to be done to approach a complete model for the system.

Acknowledgements

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