OBSERVATIONAL STUDIES OF 12DD LACERTAE

I: Multiperiodicity and Its Variations

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Abstract. Analysis of the light curves of 12DD Lacertae obtained during the years 1918–71 shows that the primary period, $P_1$, is decreasing at the rate of about 1 s per 500 yr. The secondary period, $P_2$, is nearly constant but the third and fourth periods, $P_3$ and $P_4$, appear unstable with some irregular changes in frequency and amplitude. It is confirmed that the color in the primary variation is bluest around the phase of a half quarter before maximum light, $0.875$. The third variation also shows a similar tendency in color, while the secondary and fourth variations do not seem to show any meaningful color change, presumably indicating that the latter two are different from the pulsational nature of the primary and third variations. The method of power spectrum analysis is further applied to examine the structure of the multiperiodicity in more details and to search for any unknown periods in the light variation.

1. Introduction

12DD Lacertae is a well-known member of the $\beta$ CMa type variable stars, and since the early years of this century the photometric and spectroscopic observations have been made by many observers. The multiperiodicity in the light variations of this star was first recognized by Fath (1938) and the pulsational character has been discussed by various workers from its color variation and the phase relation between the radial velocities and the light curves. The international co-operative observations organized by C. de Jager in 1956 revealed that there exist four distinct periods in the light variations of 12DD Lacertae (de Jager, 1957). The resulting complicated behavior of the light variations of this star has stimulated us to study the physical conditions of the star in details. Using the observational data obtained during the years 1918–59 and our observations of 12DD Lacertae made during 1962–71, we try to analyze the complicated phenomena of this $\beta$ CMa type variable so that the light and color variations obtained through these over 50 yr are described as accurately as possible.

The principal purpose of this Paper I is to re-determine the values of accurate multiperiods and also examine their color variations from all of the data.

2. Observational Data

In the present analysis for 12DD Lacertae we used our UBV photoelectric observations and the previous photoelectric ones by Guthnick (1919), Fath (1938), Green (1941), de Jager (1953), Lynds and Thomas (1957), and Opolski and Ciurla (1961). The photographic observations by Christie (1928) were also adopted. Our photoelectric observations were made in 1962–66 with the 91 cm reflector at the Okayama Astrophysical Observatory and in 1971–72 with the 25 cm reflector at Akita University.
Photoelectric installations at the Okayama Astrophysical Observatory are well known as unrefrigerated ones furnished with an EMI 6256B photomultiplier tube and Matsuda color filters of UVD1C (for U), UV39 + VV42 (for B), and VO51 (for V), while those at Akita are similar ones furnished with the same type of EMI photomultiplier tube and the same Matsuda color filters. These Matsuda color filters are quite similar to the standard UBV ones by Johnson and Morgan (1953). The calibration of photometric systems between Okayama and Akita has been most carefully done, although both are nearly the same ones. The values of the transformation coefficients to the standard UBV system are determined from observations of standard stars at the respective observatories, and we use the values of \( \varepsilon = 0.08 \), \( \mu = 0.91 \), and \( \psi = 1.090 \) for the Okayama observations and \( \varepsilon = -0.03 \), \( \mu = 0.939 \), and \( \psi = 1.053 \) for the Akita observations, where the notations \( \varepsilon \), \( \mu \), and \( \psi \) have usual meanings (Hardie, 1962). All the UBV data of our observations expressed in \( (m_{\text{var}} - m_{\text{comp}}) \) are tabulated in Table II, where 10 Lacertae is used as the comparison star. The V-light curves are also shown in Figure 6.

3. Reduction

First, from all the light curves of 12DD Lacertae obtained during the years 1918–71, we shall deduce epochs of maximum light in the light variation in order to re-determine the primary period \( P_1 \). In doing so, we may neglect the effect of other superposing periodic variations on the epochs because of their small amplitudes. With various values of the primary period formerly determined by various workers (de Jager, 1953; Opolski and Ciurla, 1961), \( (O - C)_1 \)-values of observed minus computed epochs of maximum light are deduced and they are plotted in Figure 1a as a function of time expressed in the unit of year. From a mere inspection of Figure 1a we can easily recognize that the period is changing through these over 50 yr, though it is not proved to be real when a shorter interval is considered. In order to get a better fitting so as to diminish the \( (O - C)_1 \)-values for the epochs in Figure 1a, we have taken the second term into account as follows:

\[
(\text{Max})_1 = JD (\text{Hel.}) 2421914.20 + 0.19308909E - 6.647 \times 10^{-12}E^2, \quad (1)
\]

where the coefficients are determined with the least-squares method and the values in parentheses are the estimated mean errors. The resultant \( (O - C)_1 \) values with ephemeris (1) are shown in Figure 1b. The ephemeris (1) means that the primary period is decreasing at the rate of about 1 s per 500 yr. With the phase calculated by Formula (1) all the individual V-observations are plotted in Figure 2a, where a normal point is given for the mean phase at intervals of 0.05. From the normal V-light curve in Figure 2a, the mean amplitude of the light variation can be estimated to be 0.078. Similarly, the same procedures are applied for all the B- and U-observations. By combining three normal light curves in U, B, and V, the corresponding primary normal color curves in \( (B - V) \) and \( (U - B) \) are obtained as shown in the lower parts of Figure 2a. The normal color curves thus obtained show that the star is bluest around