COMMISSION 27 OF THE I. A. U.
INFORMATION BULLETIN ON VARIABLE STARS
Number 3536

Konkoly Observatory
Budapest
1 November 1990

HU ISSN 0374 - 0676

The X-Ray Source HD 197010 is an Eclipsing Binary

From an examination of the Einstein Observatory Extended Medium Sensitivity Survey, Fleming et al. (1989) compiled a list of seven stars expected to be W UMa systems. In a continuing investigation of these systems we have observed six of them. We have published results on 1E1654.0+3515 (Robb 1989), 1E1806.1+6944 (Robb and Scarfe 1989), 1E2119.7+1655 (Robb 1990) and reports on others are in preparation. This is a report of our observations of another of the stars on the list, namely HD 197010 = SAO 144692 = BD -1 4025 = 1E2038.3-0046. Its position at Right Ascension $+20^{h}38^{m}20^{s}.2$ and Declination $-00^{o}46'26''$ (Equinox 1950), brightness of 9.35 in the V band and spectral class of F8 were given by Fleming et al. (1989). A finder chart adapted from Papadopoulos et al. (1980) is given for this star in figure 1.

HD 197010 was observed using the 0.5 meter reflector of the Climenhaga Observatory at the University of Victoria on two nights in November 1989 and fourteen in August and September 1990. Computer control of the telescope allows us to point it at each of the stars at the beginning of the night and then leave it to follow a program of observations until the star reaches too large an airmass. Due to the close similarity of the variable, comparison and check stars in both position and color, mean extinction and transformation coefficients were used to correct the differential magnitudes to the Johnson V and Cousins R system (Landolt 1983). The observations of the variable star were bracketed by observations of the comparison star SAO 144708 = BD -00 4068 = HD 197105, whose constant brightness was monitored with 471 observations of the check star, SA 112 1242 = SAO 126119 = BD -00 4072 = HD 197232 (Landolt 1983). The mean check star minus comparison star magnitude was 0.360 ± 0.028 in V and 0.348 ± 0.029 in R. The errors are standard deviations about the mean, and assure the constancy of the comparison and check stars at this level, even though the uncertainties are unusually large because of the stars' low declination and the consequent bright sky background. Means of each of the fifteen nights data were calculated and the standard deviation of the nightly means was 0.009 in the V and R bands, assuring the night to night variations of the stars and the system were less than this amount.

An initial estimate of the period was found using a program based on the Phase Dispersion Minimization method of Jurkevich(1971). Plotted in figure 2 is the average standard deviation of forty phase bins as a function of the inverse period. The deep minimum at 1.41 inverse days indicates the orbital period of the system, and the shallow minima are one-day aliases and simple fractions of the real period. Inspection of a similar plot using 60 phase bins and a finer spacing of trial periods indicates a period of 0.71017 ± 0.00015 days.

Times of minimum brightness were found using a program based on the method of Kwee and Van Woerden (1956) and checked using the tracing paper method. Observations in each color were treated individually, but since there were no significant differences between the times obtained, they were combined in a mean, weighted inversely by the error in each color's determination. The heliocentric times of extrema based on all points within 0.04 days of the extrema are given in Table 1. The asymmetrical maxima shown below indicate that the minima may also be asymmetrical making the times of minimum light a function of the range of phase considered. The period found from the four times of minimum light was 0.7105 ± 0.0007 days with residuals of about seven minutes. The

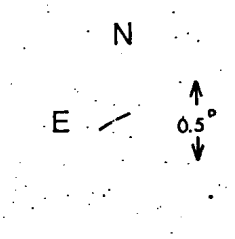

Figure 1. - Finder chart for X-Ray source, HD 197010; centered on Right Ascension 20:38:20.2 and Declination -00:46:26 (1950.0).

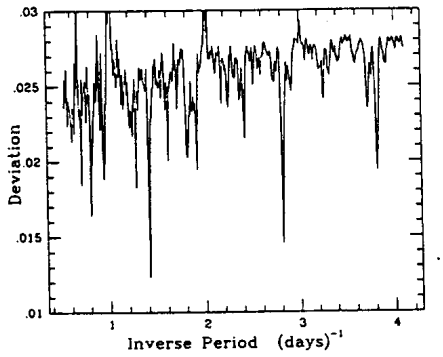

Figure 2. - Average standard deviation of forty bins versus inverse period.

Table I.
Heliocentric Julian Date of Minima - 2440000.0.

Primary Minima	Secondary Minima
8138.7196	8139.7936
13	15
8140.8511	8144.7621
4	5

points from the two nights in November 1989 were from the eclipse parts of the light curve, but could not supply a time of minimum. However for these points to be on the light curve the period had to be adjusted. The ephemeris best fitting the light curve is found to be:

Helio. J. D. of Primary Minimum = 2448140.8505(24) + 0.71017(7)E.

This period is too long to be in good agreement with the period-color relation of Eggen (1967) for contact binaries.

Due to the rather large errors in our observations, the observations have been combined into the sixty V and R band normal points plotted in figures 3 and 4. The error bars represent one standard deviation of the mean. This curve clearly shows the variation expected for an eclipsing binary system. The difference in depth of the minima show that the two stars are of different temperature

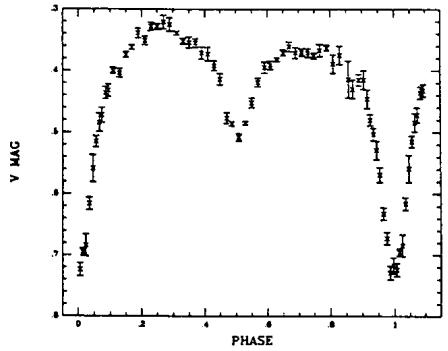

Figure 3. - V filter light curve normal points plotted with PHASE = (JULIAN DATE - 2448140.8505) / 0.71017.

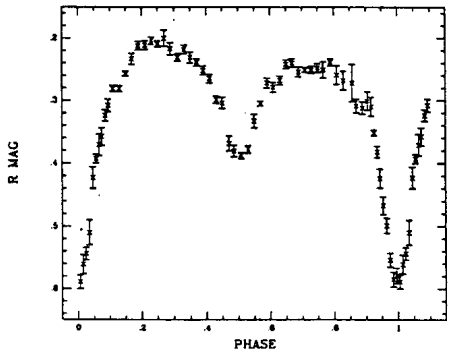

Figure 4. - R filter light curve normal points plotted with PHASE = (JULIAN DATE - 2448140.8505) / 0.71017.

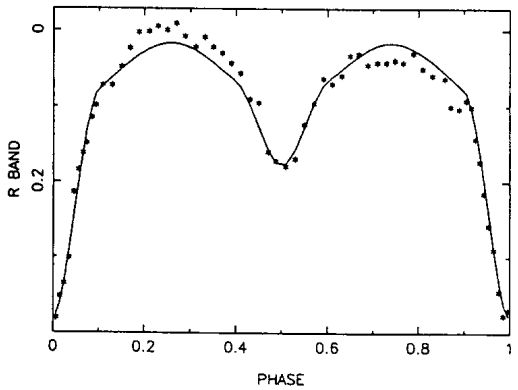

Figure 5. - R band normals points plotted with model light curve assuming both stars fractional radii are 0.31, hot star's temperature is 6300 degrees, cool star's temperature of 4800 degrees, mass ratio of 0.7 and an orbital inclination of 68 degrees.

and thus not in good thermal contact. The large difference in the brightness of the maxima showed no obvious variation from the first of August until the end of September. The (V-R) color curve shows no obvious trends.

A computer modelling program written by G. Hill (1979) was used to find approximate elements of the system. From the spectral classification of F8 from (Fleming et al.1989), we assumed a temperature of 6300 degrees Kelvin and a convective envelope with full limb darkening. The atmospheres were assumed to be black bodies. Three radial velocities are available from Fleming et al. (1989) and allow us to estimate the amplitude of the radial velocity of the bright star to be about 110 kilometers per second, but give no information as to the mass ratio of the system. Since the spectrum shows only the lines of the bright star, we assumed a mass ratio of 0.7. As shown in figure 5 the best match was found for both stars having fractional radii of 0.31, an orbital inclination of 68 degrees and a temperature for the secondary of 4800 degrees. Both stars are inside their Roche lobes for mass ratios greater than about 0.6. With this assumed velocity the primary star is roughly the accepted mass and radius of a F8 dwarf, but the seconday star is much too large for its mass and temperature. The rotational velocity from this model is consistent with the observation of Bergoffen et al.1988. These elements must be regarded as very preliminary values, since the observed light curve shows a large asymmetry in the brightness of the maxima and the mass ratio is unknown.

The X-ray source HD 197010 is an eclipsing system with a period of 0.710 days, a depth of primary minimum of 0.4 magnitudes, and a large asymmetry of the maxima. This type of asymmetry is generally attributed to star spots, which may also be the source of the observed X-Rays (Fleming et al.1989). More spectroscopic observations of this system will be important to find the component masses and mass ratio. Further photometric observations will be important to refine the orbital period, to permit a more detailed solution than has been attempted here, and to observe any migration of the asymmetry in the maxima that may occur.

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