The Algol-type system IU Per: A photometric study and search for pulsating components

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Abstract

Complete CCD light curves of the Algol-type eclipsing binary IU Persei have been obtained in the B, V, R and I filters during 7 nights in 2006 and 3 nights in 2007 with the 40-cm telescope of the Gerostathopoulion Observatory of the University of Athens. The light curves were analyzed with the W-D program in order to determine the geometrical and photometric elements of the system. Moreover, the outside eclipses light variations have been used for searching of pulsating component (s) in the system.

1. Introduction

IU Per (α_{2000} = $02^h\,59^{min}\,37^{sec}$, δ_{2000} = $43^\circ\,55'\,18''$) is an Algol-type (EA) eclipsing binary star with spectral type A4+[G6IV]. This system is listed in several catalogues of variable stars where times of minima are given. There is only one light curve solution given by Budding et al. (2004) which Kim et al. (2005) took into consideration in their study, in order to plot the phase diagram of the system. They also used the ephemeris MinI (HJD) = 2452500.214+0^d.8570257 × E, given by Kreiner (2004), and discovered a short-periodic pulsating component in the system, suggesting that IU Per is a new member of oscillating EA stars (oEA), a group of mass-accreting pulsating components in Algol-type semi-detached eclipsing binary systems. Their observations were made in Johnson B filter only. No spectroscopic study of the system exists so far.

2. The observations

The observations of IU Per were carried out during four nights in November 2006 (R and I filters), three nights in December 2006 (V filter) and one night in November 2007 and two nights in December 2007 (B filter). The 40 cm Cassegrain telescope of the Observatory of the University of Athens, equipped with a ST8XMEI SBIG CCD camera, was used. The data reduction (differential photometry) was made with the program AIP4WIN (Berry & Burnell, 2000). The stars GSC 2859-0794 and GSC 2858-2003 where used as comparison and check star, respectively.

Using the method of Kwee & van Wöerden (1956) new times of minima were calculated from our observations and they are given in Table 1.

Table 1. The new times of minima from our observations

HJD	error	type	filter
2454047.5720	0.0006	II	R, I
2454048.4234	0.0036	II	R, I
2454051.4275	0.0003	I	R, I
2454054.4253	0.0014	II	V
2454056.5697	0.0003	I	V

3. Light curve solution

The following new ephemeris, calculated by using all the available times of minima since 2004, was used for the phase diagrams:

MinI (HJD) = 2454051.42693 + 0^d.8570234 × E
± 0.00135 ± 0.0000021

The light curve analysis was made with the PHOEBE 0.28 program (Prša and Zwitter, 2005) which uses the 2003 version of the Wilson-Devinney code (Wilson and Devinney, 1971; Wilson, 1979). The analysis was carried out by assuming that there are no spots on the components of IU Per, since there are no light variations suggesting spot activity. The code was applied in mode 2 (detached binary), mode 4 (semi-detached binary, primary star fills Roche lobe) and mode 5 (semi-detached binary, secondary star fills Roche lobe) to each filter individually. Since no spectroscopic observations are available, initial values for the mass ratio (q=0.27) and the inclination (i=82°) were adopted from the tables by Budding et all. (2004). The fixed value of the primary star temperature (T_1=8450 K) was obtained from its spectral type. The gravity darkening coefficients g_1, g_2 and the albedos A_1, A_2 of the primary and secondary components, respectively, were set to the theoretical values. The limb darkening coefficients x_1, x_2 were supplied by the code. The subscripts 1 and 2 refer to the star being eclipsed at primary and secondary minimum, respectively.

The solutions converged in the modes 2 and 5 of the program. The best fit, i.e. minimum x^2 value, was achieved with mode 5 in all four filters, indicating that the secondary star fills its Roche lobe. The parameters derived from the solutions in mode 5 are given in Table 2 and the theoretical light curves of mode 5 solution, along with the observed ones, only for V filter, are shown in Figure 1. A three dimensional model of the system and a surface outline, derived from the program Binary Maker 3 (Bradstreet and Steelman, 2004) are shown in Figure 2.

Table 2. Parameters of light curve solution in mode 5

parameter	filter B	filter V	filter R	filter I
i (degrees)	80.67 (6)	79.95 (12)	81.56 (16)	79.10 (9)
T_1 (K)	8450*	8450*	8450*	8450*
T_2 (K)	5013 (7)	4765 (15)	4846 (9)	4729 (7)
q (=m_2/m_1)	0.2387 (11)	0.2188 (23)	0.1801 (16)	0.2080 (15)
Ω_1	2.9115 (56)	2.9094 (141)	2.8168 (95)	2.8184 (88)
$\Omega_2=\Omega_{in}$	2.3295*	2.2818*	2.1822*	2.2327*
$L_1/(L_1+L_2)$	0.9553 (5)	0.9841 (11)	0.9244 (9)	0.8846 (8)
$L_2/(L_1+L_2)$	0.0447	0.0159	0.0756	0.1154
x_1	0.5534*	0.4832*	0.3910*	0.2993*
x_2	0.8629*	0.7615*	0.6166*	0.5129*
g_1, g_2	1.0*, 0.32*	1.0*, 0.32*	1.0*, 0.32*	1.0*, 0.32*
A_1, A_2	1.0*, 0.5*	1.0*, 0.5*	1.0*, 0.5*	1.0*, 0.5*
r_1 (pole)	0.372	0.381	0.381	0.381
r_1 (point)	0.398	0.408	0.408	0.408
r_1 (side)	0.385	0.395	0.395	0.395
r_1 (back)	0.392	0.402	0.402	0.402
r_2 (pole)	0.245	0.236	0.236	0.236
r_2 (point)	0.358	0.345	0.345	0.345
r_2 (side)	0.255	0.245	0.245	0.245
r_2 (back)	0.287	0.277	0.277	0.277
χ^2	0.129427	0.034037	0.213693	0.161864

* assumed

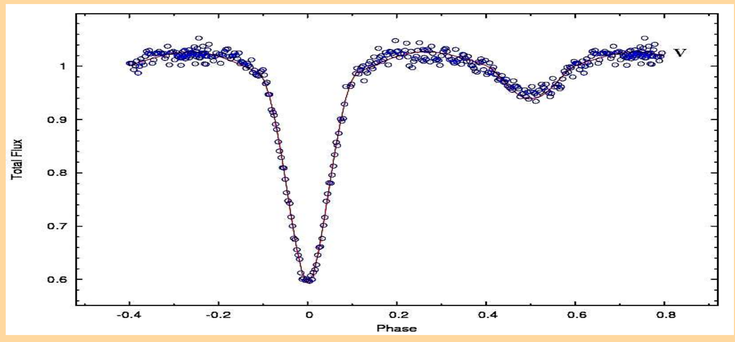

Fig. 1. Observed (circles) and theoretical (solid line) light curves of IU Per.

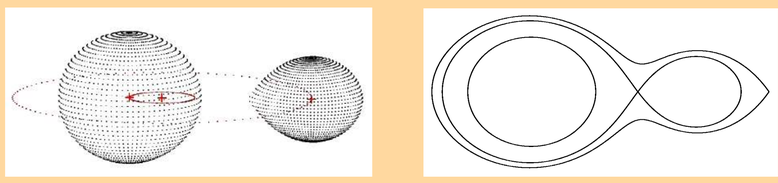

Fig. 2. A three dimensional model of the system (left) and a surface outline (right) at phase 0.25.

4. Pulsation of the primary component

In order to search for short-period pulsations in the system, the theoretical light curve in the B filter was subtracted from the observed one. We used only B filter because the corresponding light curve is the only one which shows periodic changes at some specific orbital phase intervals. We performed the frequency analysis on this residual light curve using the Period04 software (Lenz and Breger 2005), which is based on the classical Fourier analysis. As the light curve in B has too many points, we did not include all orbital phases. We select only some small parts of the light curve and we performed the frequency analysis on each one of then separately.

The results of the frequency search are shown in Table 3: we list the orbital phase intervals, the corresponding most significant frequency value with its error and the semi-amplitude, derived from a multi-parameter least-squares fit of sinusoidal functions, with its error. The dominant frequency (mean value) corresponds to a period of 34 minutes and the amplitude changes from cycle to cycle. These results are in agreement with those derived by of Kim et al. (2005). Figure 3 illustrates the frequency analysis on the phase interval 0.55-0.65 and the corresponding least-square fit.

Table 3. Results of the frequency analyses of the residual data of IU Per in B passband.

phase	frequency (c/d)	σ_f (c/d)	amplitude (mag)	σ_a (mag)
0.10 - 0.15	47.862	1.437	0.0081	0.0009
0.35 - 0.40	37.945	2.631	0.0057	0.0014
0.55 - 0.60	42.221	0.890	0.0064	0.0008
0.85 - 0.90	46.194	2.729	0.0057	0.0012

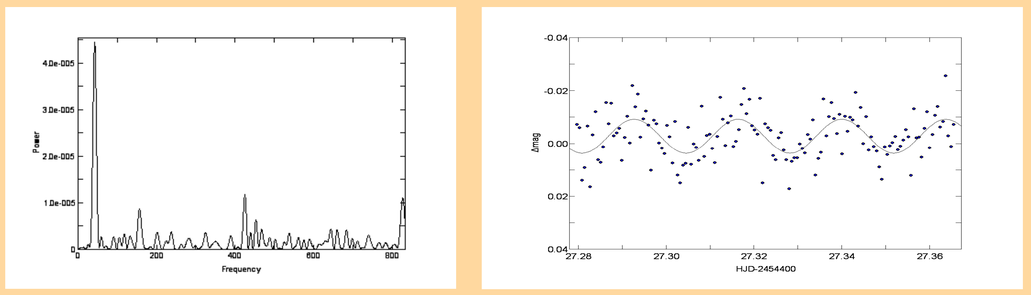

Fig. 3. The frequency analysis on the phase interval 0.55-0.65 (left) and the corresponding least square fit (right).

4. Summary and Conclusions

Complete multicolour light curves and photometric analysis of IU Per are presented for the first time. The results obtained from the light curve analysis show that IU Per is most probably a semi-detached binary system whose secondary component fills its Roche lobe. Moreover, the frequency analysis performed on residual light curve in B filter confirms that the system belongs to the group of oscillating oEA stars, as the characteristics of the pulsating component are the same with that of a δ Scuti star, and has a pulsation period of about 34 min.

Acknowledgements: This work has been financially supported by the bilateral program between Greece and Slovakia under the grant 70/3/8374 of the NKUA/SARG and the grant 70/3/7849 of the NKUA/SARG.

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MEARIM, Cairo, Egypt, April 5-10, 2008