COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 6096

Konkoly Observatory
Budapest
24 February 2014

HU ISSN 0374 – 0676

RADIAL VELOCITY SOLUTION OF THE SYSTEM IP Dra

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The light variability of IP Dra with an amplitude of $0\overset{m}{.}06$ and a period of 1.7184 days was detected by *Hipparcos* (ESA 1997) and the star was classified as EB of β Lyr type. The available data for this star are: V=$7\overset{m}{.}76$, $B-V$=$0\overset{m}{.}535$, $V-I$=$0\overset{m}{.}61$, parallax 8.27 mas (distance 121 pc), spectral type F5, age 2.7 Gyr (ESA 1997; Kazarovets et al. 1999; Nordström et al. 2004; Malkov et al. 2006).

In order to obtain radial velocity solution of IP Dra we acquired few tens of spectra with the 2-m telescope of the National Astronomical Observatory at Rozhen (Table 1). We used a CCD Photometrics AT200 camera with the SITe SI003AB 1024×1024 pixels chip mounted on the coudé spectrograph (grating B&L632/14.7°). The exposure time was 15 min and the mean S/N ratio was around 60-70.

Table 1. Journal of observations.

Year	Month, date	number of spectra	Phase range
2004	Aug 25	4	0.545-0.685
2005	Jul 29	2	0.675
2006	Feb 03	2	0.295
2006	Feb 04	4	0.805-0.825
2006	Feb 07	11	0.594-0.755
2006	Jun 21	8	0.524-0.60
2006	Jun 22	6	0.101-0.186
2006	Jul 18	3	0.31, 0.365
2006	Jul 19	14	0.792-0.956
2007	Feb 09	1	0.175
2007	Mar 24	5	0.282-0.322
2007	Aug 07	7	0.295-0.435
2007	Aug 08	4	0.006-0.030
2007	Dec 21	1	0.491
2010	May 03	2	0.96
2013	Aug 25	1	0.52

Most of the spectra were in the spectral range around the Hα line (6470-6670 Å) with 0.19 Å/pixel resolution and they covered well the orbital cycle. Moreover, several spectra around the CaII H & K and NaD lines were obtained.

The spectral data were reduced in a standard way using the PCIPS software packages (Smirnov et al. 1992) by bias subtraction, flat-field division and wavelength calibration (with Th-Ar comparison source exposures). β Vir was used as a radial velocity standard.

Our data were phased according to the ephemeris of *Hipparcos* (ESA 1997):

$$\mathrm{MinI} = 2448501.317 + 1.7184 \times \mathrm{E}\ .$$

Normalized H_α spectra around characteristic orbital phases are shown in Fig. 1.

The profiles of the Hα line of IP Dra are single-shaped at all phases and their strength is appropriate to the spectral type F5 of the primary. The profiles of the CaII H & K and NaD lines (Fig. 2) also correspond to the F5 primary and do not reveal contribution of the secondary. These facts allowed us to classify the target as a single-lined spectroscopic binary with a low-luminosity secondary.

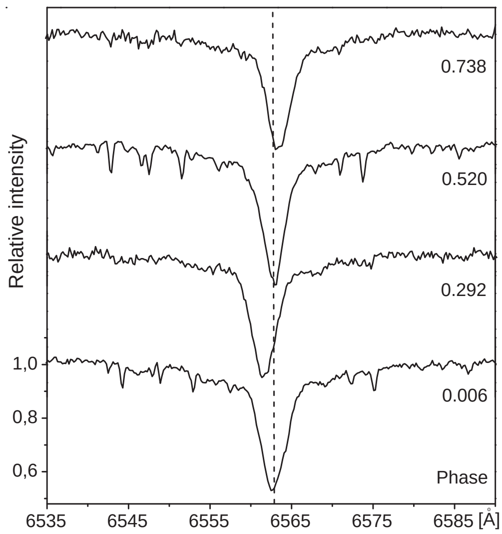

Figure 1. The Hα lines of IP Dra around the eclipses and quadratures.

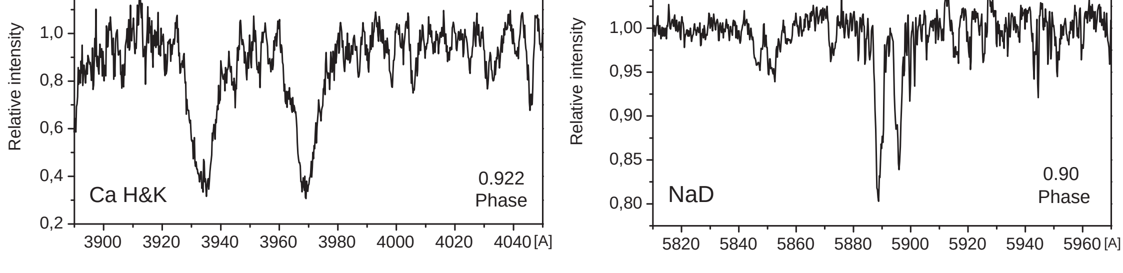

Figure 2. The spectra of IP Dra around the CaII H & K lines (left) and NaD line (right) from July 19 2006.

The FWHM, EW and depth of the Hα line change during the cycle correspondingly in the ranges 3.2-3.9 Å, 2.1-3 Å and 0.48-0.63. Their variability do not reveal any considerable trends with phase.

The Doppler shifts of the Hα line (Fig. 1) confirm that IP Dra is a binary system. The measured radial velocities were fitted by a sinusoid with a semi-amplitude $K_1 \sin i$=65.7±1.6 km/s and a systemic velocity V_0=3.6±2.1 km/s (Fig. 3).

In order to obtain estimations of the fundamental parameters of IP Dra we made some speculations based on its photometric and spectral observations.

The small-amplitude quasi-sinusoidal light curve of IP Dra (ESA 1997) implies ellipsoidal variations rather than eclipses because even grazing eclipses would cause some sharp dips in the light curve. The absence of spectral features from the secondary means that its luminosity should be less than 10% of that of the primary.

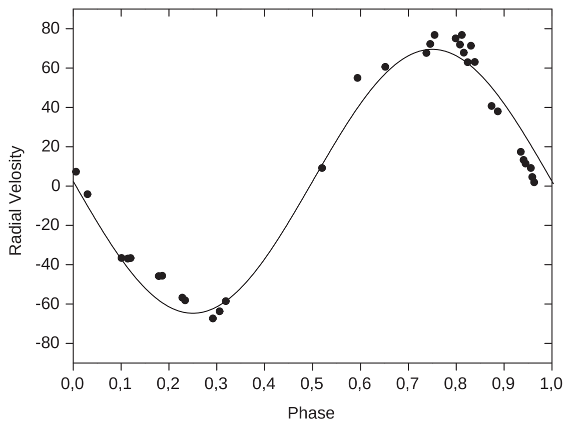

Figure 3. Radial velocity data of IP Dra and their fit.

The solution of the available low-precision, quasi-sinusoidal (*Hipparcos*) light curve is quite ambiguous, i.e. it may be reproduced with a great number of combinations of parameters whose values are within large ranges. The number of solutions can be reduced if one assumes that the two components are MS stars and uses the known empirical relations.

Thus the upper limit L_2=0.1L_1 allowed us to fix mass ratio q=0.56, secondary temperature T_2=0.708T_1=4600 K and relative radius of the secondary r_2=0.65r_1. As a result we obtained solutions within narrow ranges of the fitted parameters r_1 (relative radius of the primary) and i (orbital inclination), namely 0.39–0.43 and 50.5–37.5°. For the reasonable low limit L_2=0.01L_1 we fixed q=0.316, T_2=0.5T_1=3250 K, r_2=0.422r_1, and obtained even narrower ranges of the fitted parameters r_1 and i: 0.48–0.482 and correspondingly 50–40°.

The presented considerations led us to the conclusion that IP Dra is (or almost is) a semidetached binary with a low-luminosity secondary component.

The mean rotational broadening of the spectral lines of IP Dra corresponds to $V_1^{eq} \sin i$=73 km/s. This means $V_1^{eq} \geq 95$ km/s (equality for $i = 50°$). If IP Dra is a synchronized binary (P_{orb}=P_{rot}) this result leads to an absolute radius $R_1 \geq 3.24$ $R_\odot$. Thus the primary is oversized for an F5 MS star. This conclusion from our spectroscopy supports the big relative radius of the primary derived from the light curve solution.

Acknowledgement: Based on spectral observations collected at the National Astronomical Observatory at Rozhen. The research was supported partly by funds of a project of

Scientific Foundation of Shumen University. We are grateful to the anonymous referee, and the editor, László Molnár, for the useful notes.

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