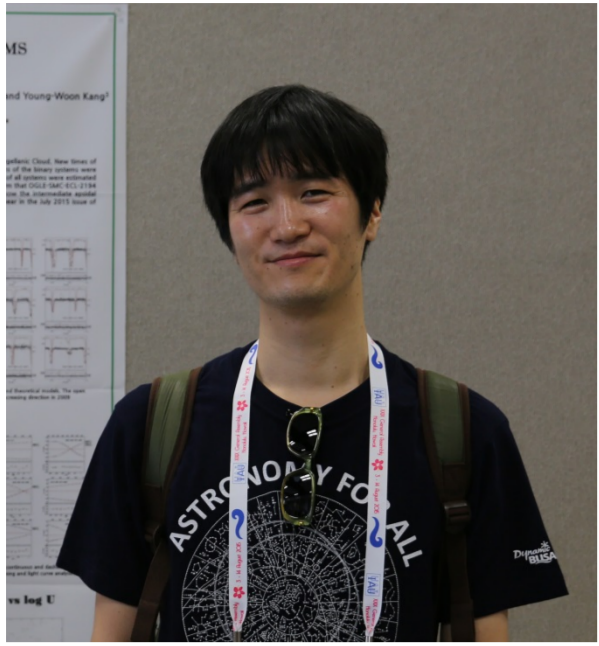


Time-series spectroscopy of the eclipsing binary AB Cas with a pulsating component



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Abstract

We present high resolution spectra of the eclipsing binary AB Cas with a δ Sct-type pulsating star, which were obtained using the Bohyunsan Optical Echelle Spectrograph in Korea. The radial velocities (RVs) for the primary and secondary components are measured from a total of 27 spectra, secured during 2 nights on October 2015. In order to obtain the accurate physical properties, we simultaneously analysed our RV curves together with previously published $uvby$ light-curves. Individual masses, radii, and effective temperatures of both components are determined to be $M_1=2.01\pm 0.02 M_{\text{sun}}$, $M_2=0.37\pm 0.02 M_{\text{sun}}$, $R_1=1.84\pm 0.02 R_{\text{sun}}$, and $R_2=1.69\pm 0.03 R_{\text{sun}}$, $T_{\text{eff},1}=8,000\pm 250$ K and $T_{\text{eff},2}=4,900\pm 150$ K, respectively. In addition, we investigate the evolutionary history of AB Cas using theoretical evolutionary models to give the best representation for their physical parameters. All of these indicates that AB Cas is an oscillating Algol-type eclipsing binary (oEA) with the less massive and cool secondary star filling its inner Roche lobe, which may have experienced rapid mass transfer.

Temperature and Velocity Solutions

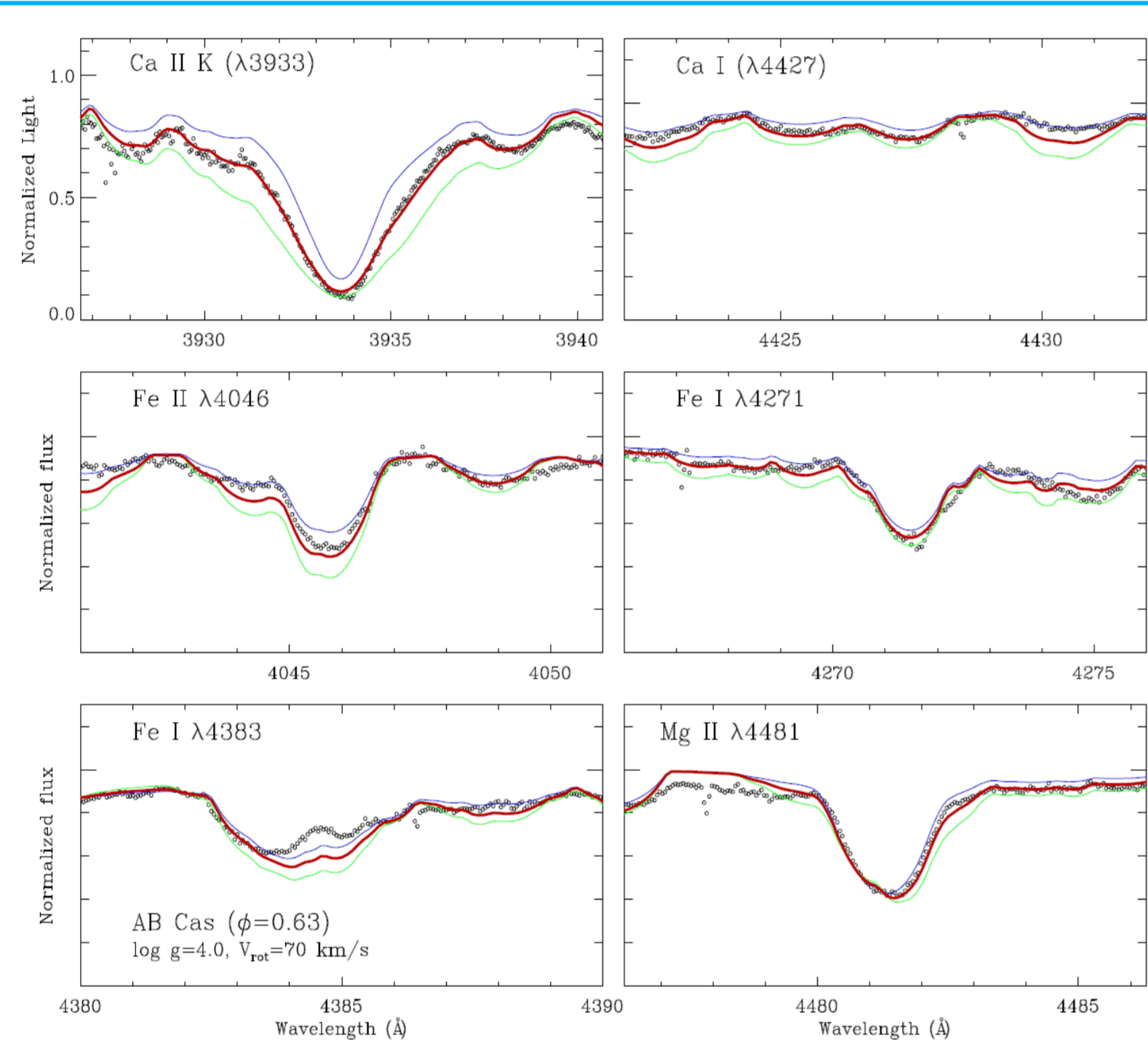


Fig. 1. High-resolution spectrum of AB Cas over six spectral ranges of special interest. The spectrum was obtained at the orbital phase of 0.63. Black dots represent observed data and blue, red, and green lines represent synthetic spectra of 8,500 K, 8,000 K, 7,500 K, respectively, from the atmosphere models by Kurucz (1993).

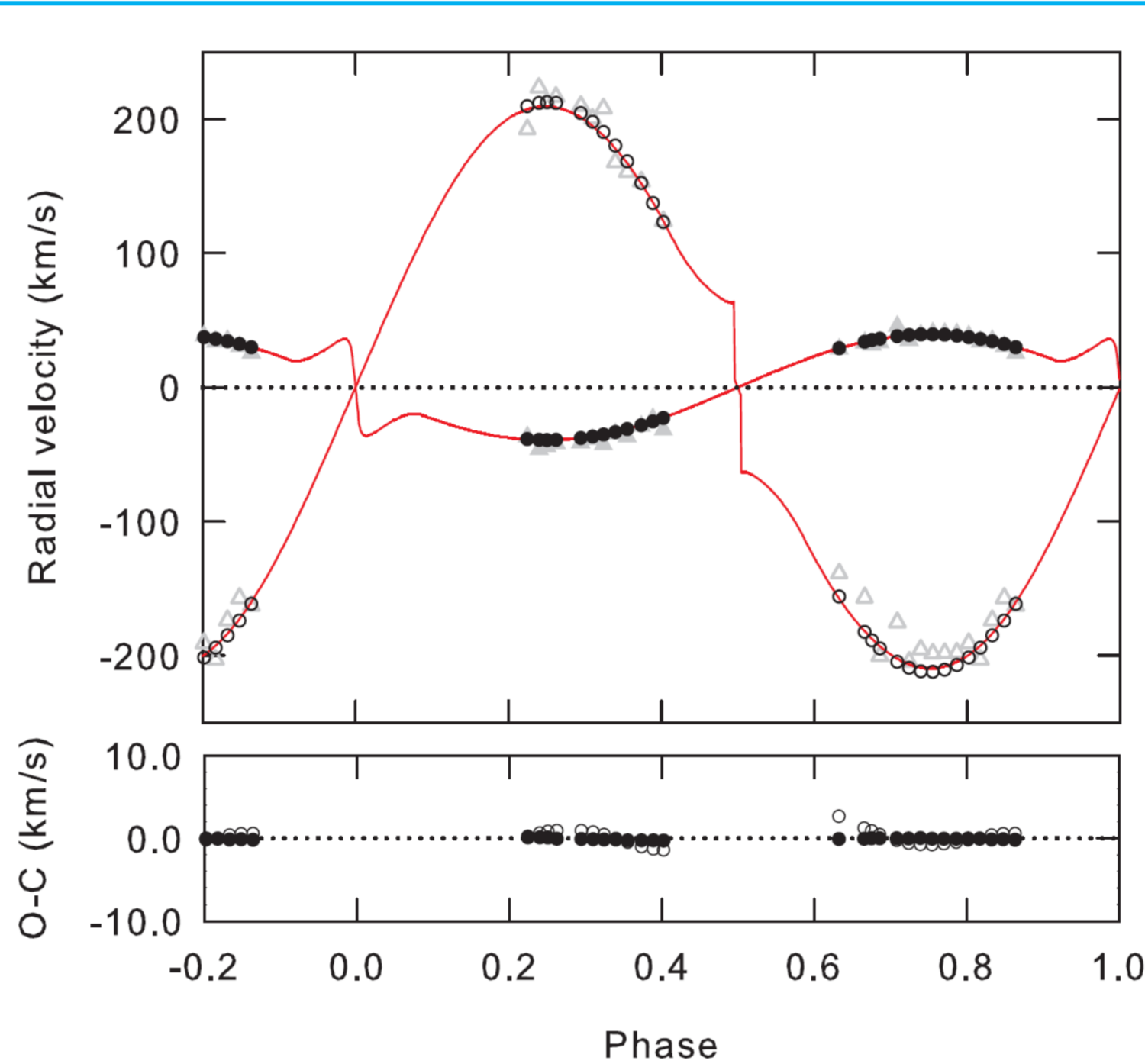


Fig. 2. Radial velocity curves of AB Cas with the fitted models. Filled and open circles represent RV measurements for primary and secondary components with FDBinary code developed by Ilijic et al. (2004), respectively. The upper panel displays radial velocities of both components with the WD runs. The lower panel is the residuals between observations and theoretical models. The triangles represent the both velocities measured using two gaussian functions.

Table 1. Radial Velocities of AB Cas

HJD (2,457,000+)	Phase	V_1 (km/s)	$(O-C)_1$ (km/s)	V_2 (km/s)	$(O-C)_2$ (km/s)
313.10682	0.2246	-38.8	0.08	209.4	0.21
313.12791	0.2400	-39.3	0.09	211.8	0.60
313.14242	0.2506	-39.4	0.05	212.3	0.80
313.15867	0.2625	-39.3	-0.08	211.7	0.91
313.20264	0.2947	-37.9	-0.11	204.3	0.91
313.22370	0.3101	-36.7	-0.14	197.8	0.71
313.24328	0.3244	-35.3	-0.20	190.0	0.42
313.26440	0.3398	-33.5	-0.18	180.0	-0.06
313.28551	0.3553	-31.3	-0.27	168.2	-0.49
313.31066	0.3737	-28.3	-0.27	152.2	-1.04
313.33174	0.3891	-25.5	-0.26	137.2	-1.30
313.35008	0.4025	-22.9	-0.29	123.1	-1.41
315.03143	0.6326	29.0	-0.13	-156.1	2.63
315.07681	0.6658	33.9	-0.08	-182.5	1.20
315.09013	0.6755	35.1	-0.03	-188.8	0.88
315.10436	0.6859	36.2	-0.02	-194.7	0.42
315.13524	0.7085	38.0	-0.04	-204.7	-0.28
315.15633	0.7239	38.8	-0.05	-209.2	-0.61
315.17760	0.7395	39.3	0.01	-211.7	-0.76
315.19869	0.7549	39.3	-0.08	-212.2	-0.79
315.21976	0.7704	39.0	-0.09	-210.7	-0.67
315.24196	0.7866	38.3	-0.10	-207.1	-0.47
315.26302	0.8020	37.3	-0.07	-201.6	-0.21
315.28412	0.8174	35.9	-0.10	-194.2	-0.02
315.30520	0.8329	34.1	-0.18	-185.0	0.36
315.32628	0.8483	32.1	-0.14	-174.0	0.52
315.34734	0.8637	29.7	-0.20	-161.5	0.54

Light curves, Binary parameters, and Evolutionary tracks

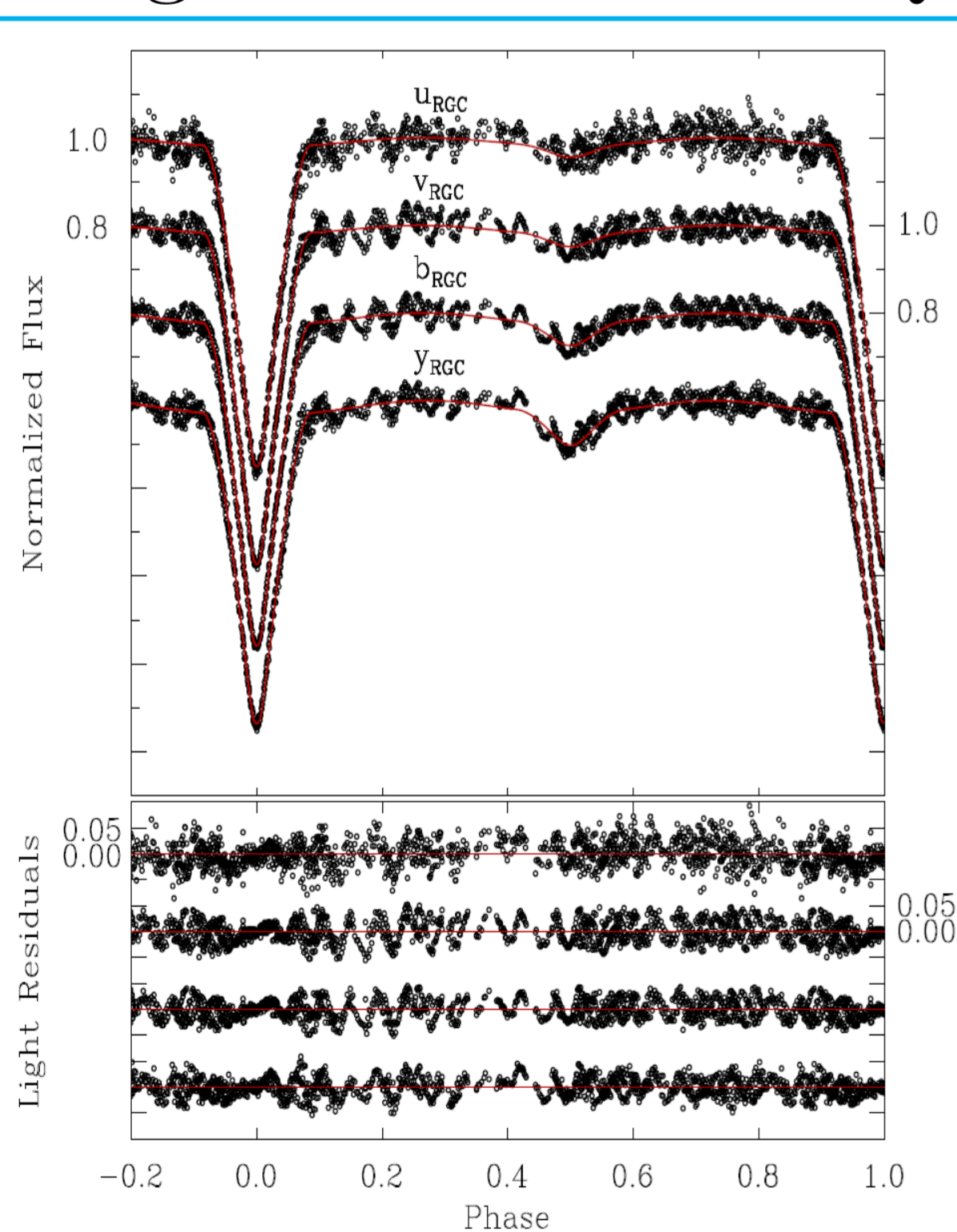


Fig. 3. $uvby$ light curves of AB Cas with fitted models. The circles are measures from the paper of Rodriguez et al. (2004, RGC). In the upper panel, the solid lines represent the synthetic curves obtained with the WD runs. The lower panel is the light residuals between measures and theoretical models.

Table 2. Binary parameters

Parameter	Primary	Secondary
T_0 (HJD)	2452501.3463 (3)	
P (day)	1.3668918 (2)	
a (R_{\odot})	6.91 (6)	
q	0.182 (1)	
i (deg)	89.3 (2)	
T (K)	8,000 (250)	4,900 (150)
Ω	3.963 (4)	2.188
$X_{\text{bol}}^a, Y_{\text{bol}}^a$	0.671, 0.195	0.631, 0.149
x_u^a, y_u^a	0.668, 0.156	0.850, -0.489
x_v^a, y_v^a	0.848, 0.314	0.857, -0.299
x_b^a, y_b^a	0.807, 0.297	0.866, -0.138
x_y^a, y_y^a	0.711, 0.262	0.808, -0.009
$l/(l_1+l_2)_u$	0.974 (14)	0.026
$l/(l_1+l_2)_v$	0.971 (13)	0.029
$l/(l_1+l_2)_b$	0.946 (16)	0.054
$l/(l_1+l_2)_y$	0.919 (19)	0.081
r (pole)	0.2641 (3)	0.2268 (8)
r (point)	0.2689 (3)	0.3332 (9)
r (side)	0.2677 (3)	0.2358 (8)
r (back)	0.2683 (3)	0.2681 (8)
r (volume) ^b	0.2665 (3)	0.2442 (8)

Table 3. Physical properties

Parameter	Abadi & Riazzi (2007)		This Work	
	Primary	Secondary	Primary	Secondary
T (K)	8,000	4,000	8,000 (250)	4,900 (150)
Mass (M_{\odot})	1.874	0.375	2.01 (2)	0.37 (2)
Radius (R_{\odot})	1.885	1.633	1.84 (2)	1.69 (3)
$\log g$ (cgs)	-	-	4.21 (1)	3.55 (1)
$\log L/L_{\odot}$	1.244 (6)	-0.034	1.098 (54)	0.171 (53)
M_{bol} (mag)	-	-	2.00 (14)	4.32 (13)
M_V (mag)	-	-	2.03 (14)	4.35 (13)
Distance (pc)	-	-	353.1 (20.9)	-

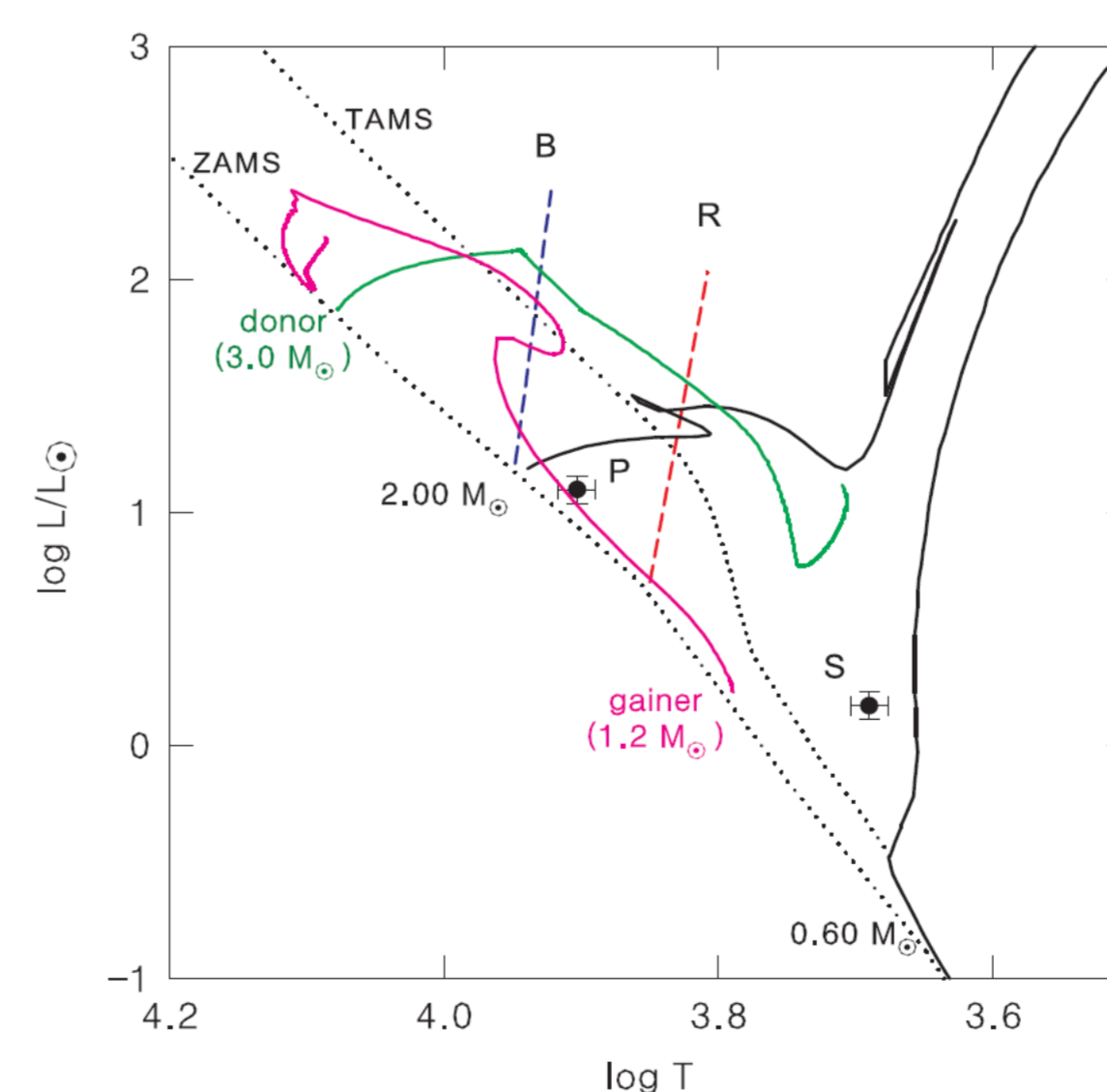


Fig. 4. HR diagram of the primary (P) and secondary stars (S) of AB Cas. The continuous black lines represent the single star evolutionary tracks for the present masses of both components of AB Cas adopted from Girardi et al. (2000). The blue (B) and red (R) edges of the δ Sct instability region are indicated. The green and pink colored lines represent theoretical evolutionary track of De Loore & Van Rensbergen (2005) for the donor ($3.0 M_{\odot}$) and gainer ($1.2 M_{\odot}$) stars in close binary system.

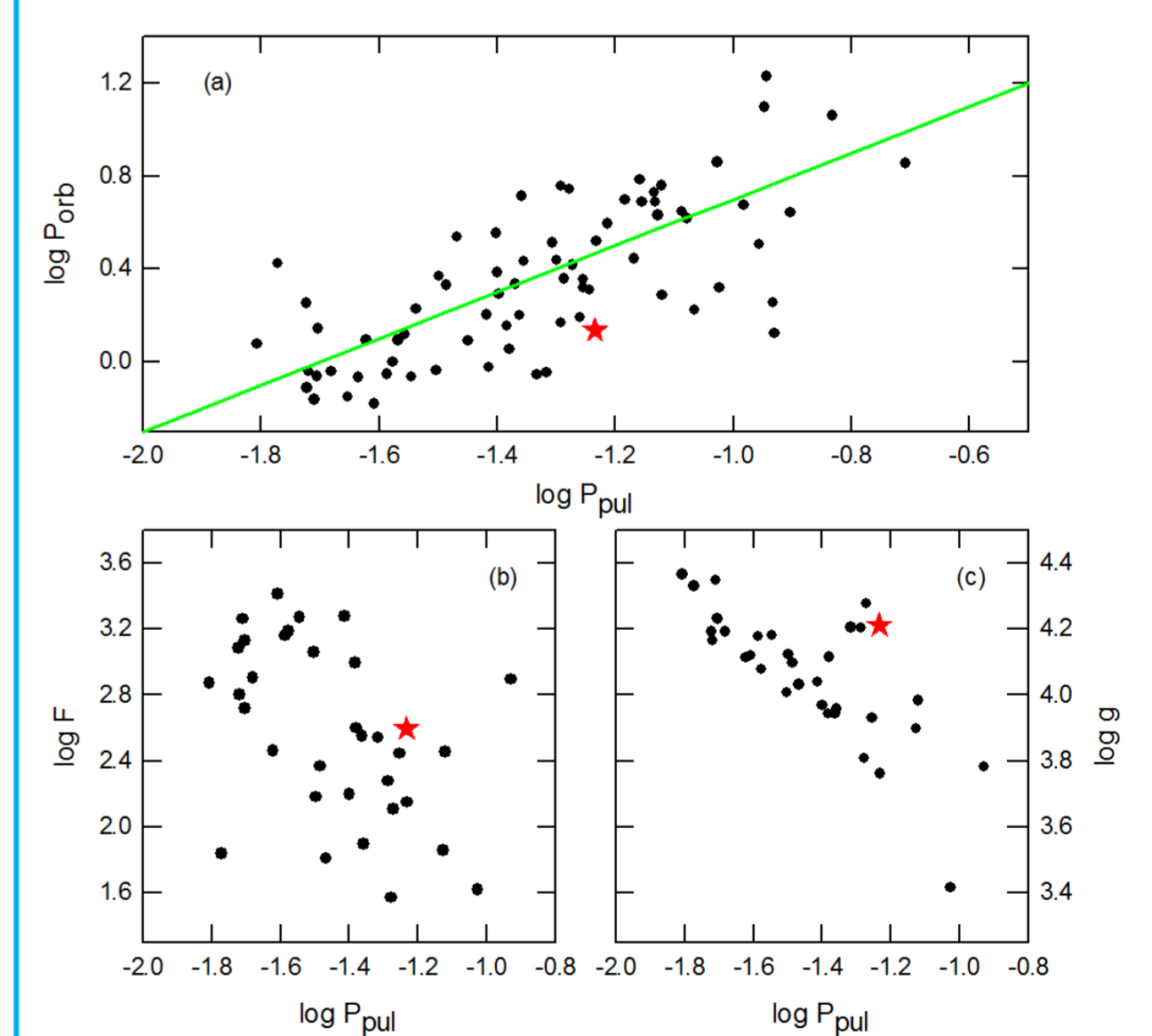


Fig. 5. Diagrams of the orbital periods (a), the gravitational forces (b), surface gravities (c) against the pulsation periods for oEA stars. The star symbols represent the parameters of AB Cas, and the solid line in the upper panel represents the relation of $\log P_{\text{pul}} = \log P_{\text{orb}} - 1.70$ given by Zhang et al. (2003).