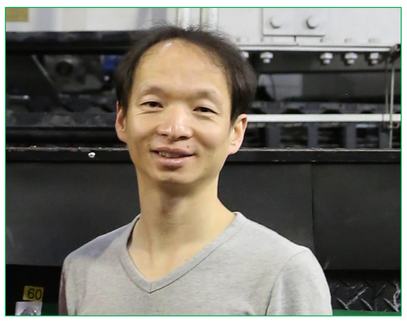

Time-series spectroscopy of the pulsating eclipsing binary XX Cephei

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ABSTRACT

Oscillating Algol-type eclipsing binaries (oEA) are very interesting objects that have three observational features of eclipse, pulsation, and mass transfer. Direct measurement of their masses and radii from the double-lined radial velocity data and photometric light curves would be the most essential for understanding their evolutionary process and for performing the asteroseismological study. We present the physical properties of the oEA star XX Cep from high-resolution time-series spectroscopic data. The effective temperature of the primary star was determined to be 7,946 ± 240K by comparing the observed spectra and the Kurucz models. We detected the absorption lines of the secondary star, which had never been detected in previous studies, and obtained the radial velocities for both components. With the published *BVRI* light curves, we determined the absolute parameters for the binary via Wilson-Devinney modeling. The masses and radii are M_1 = 2.49±0.06$M_\odot$, M_2 = 0.38±0.01$M_\odot$, R_1 = 2.27±0.02$R_\odot$, and R_2 = 2.43±0.02$R_\odot$, respectively. The primary star is about 45% more massive and 60% larger than the zero-age main sequence (ZAMS) stars with the same effective temperature. It is probably because XX Cep has experienced a very different evolutionary process due to mass transfer, contrasting with the normal main sequence stars. The primary star is located inside the theoretical instability strip of δ Sct-type stars on HR diagram. We demonstrated that XX Cep is an oEA star, consisting of a δ Sct-type pulsating primary component and an evolved secondary companion.

RADIAL VELOCITIES and TEMPERATURE

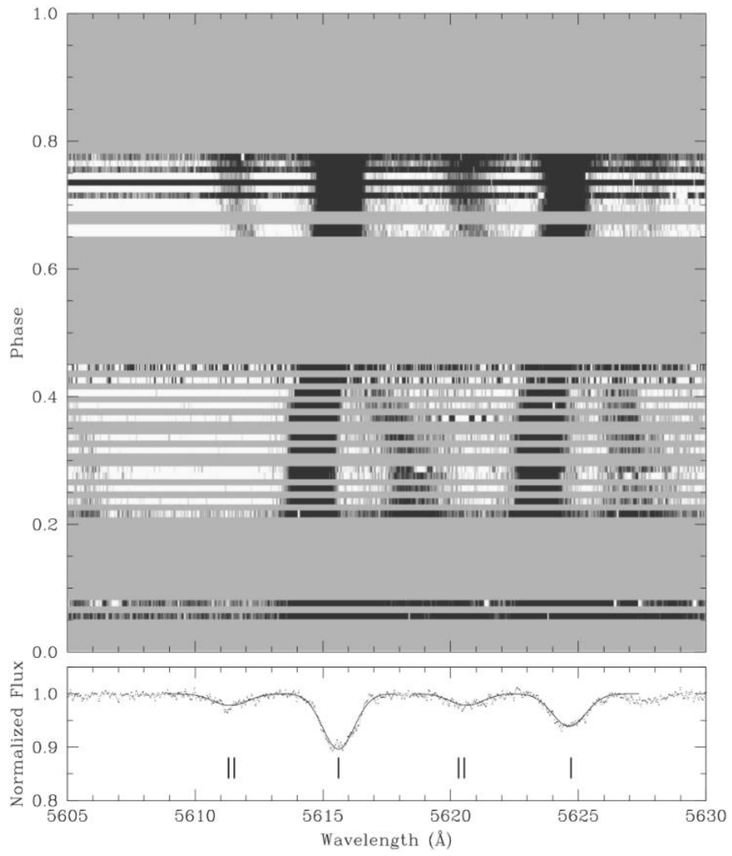

Fig. 1.— Trailed spectra and Gaussian fitting sample for RVs in the regions of Fe I λ5615.64 and λ5624.54. In upper panel, two components can be identified easily, shifted through orbital phases. In lower panel, dots and lines represent the observations and Gaussian fittings at phase of $\phi = 0.75$, respectively. '|' for primary and '||' for secondary components are marked.

Table 1. Radial velocities for XX Cep

HJD	V_1 (km s^{-1})	V_2 (km s^{-1})
2454397.2311	−40.9 ± 3.3	31.1 ± 34.8
2454397.2759	−40.1 ± 0.8	55.4 ± 7.0
2454398.1364	−32.2 ± 3.5	81.7 ± 25.0
2454401.0759	−0.1 ± 1.4	−206.6 ± 5.2
2454401.1207	1.3 ± 2.2	−211.1 ± 6.0
2454401.1650	0.6 ± 0.7	−212.3 ± 6.5
2454401.2094	1.3 ± 1.9	−212.2 ± 6.0
2454401.2537	0.7 ± 1.1	−207.6 ± 4.1
2454771.9257	−51.6 ± 1.2	122.8 ± 1.8
2454771.9702	−49.6 ± 0.8	112.6 ± 3.4
2454772.0202	−45.9 ± 1.8	96.5 ± 10.0
2454772.0826	−38.1 ± 8.1	68.2 ± 9.1
2454773.9133	−56.5 ± 0.6	151.7 ± 5.3
2454773.9578	−57.5 ± 1.8	147.8 ± 5.5
2454774.0091	−58.3 ± 2.1	155.0 ± 2.7
2454774.0535	−57.3 ± 1.7	152.4 ± 8.0
2454774.0930	−57.2 ± 2.0	152.2 ± 4.7
2454774.1531	−56.4 ± 1.3	148.8 ± 5.0
2454774.1976	−54.4 ± 1.9	135.8 ± 1.6
2454774.9356	−3.4 ± 1.2	−185.0 ± 9.9
2454774.9810	−1.5 ± 1.7	−193.5 ± 9.0
2454775.0313	0.0 ± 1.7	−202.0 ± 6.7
2454775.0756	0.8 ± 2.3	−207.2 ± 8.0
2454775.1212	1.2 ± 1.7	−213.3 ± 4.0
2454775.1654	1.6 ± 1.7	−212.4 ± 4.4
2454775.2110	1.2 ± 1.1	−209.3 ± 4.3

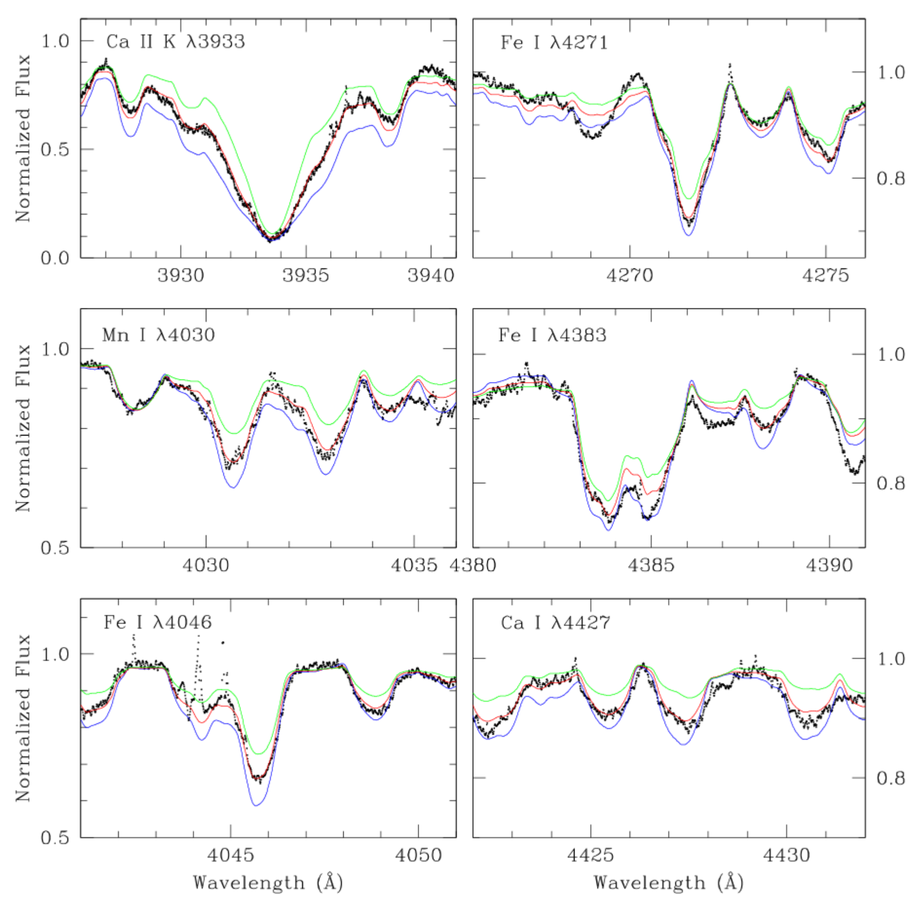

Fig. 2.— Six spectral regions of XX Cep. Dots represent the combined spectrum and blue, red, and green lines represent the synthetic spectra of $T_{\rm eff}$ = 7,500 K, 8,000 K, and 8,500 K with solar abundance, respectively.

BINARY PARAMETERS and EVOLUTION

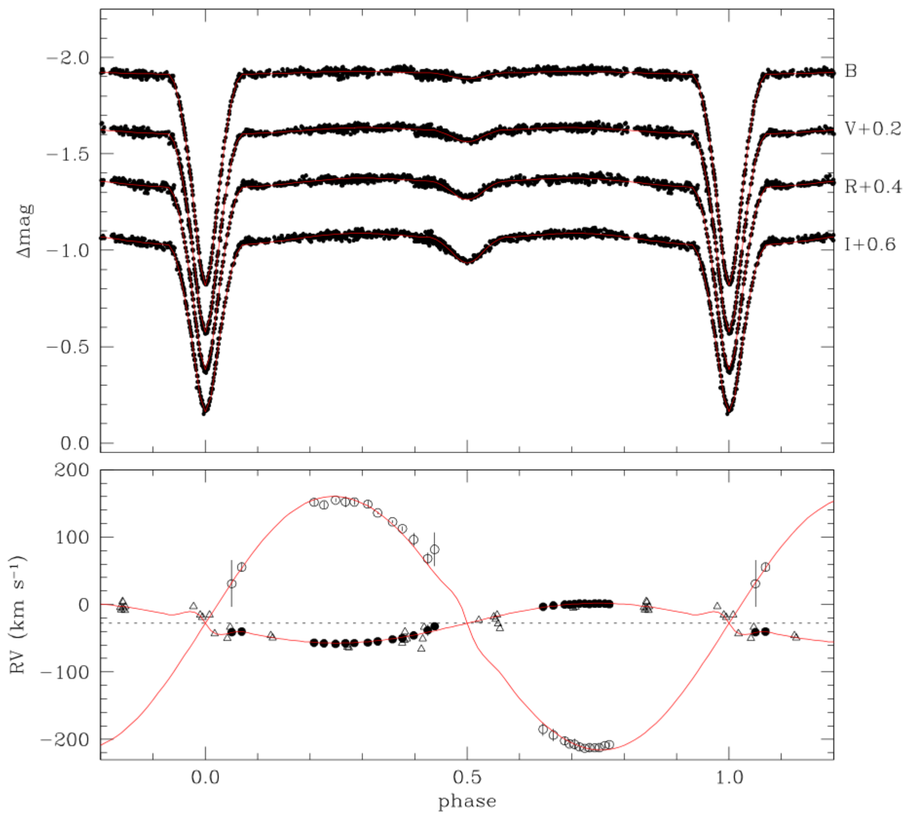

Fig. 3.— *BVRI* light and RV curves of XX Cep with fitted models. In upper panel, measurements (black dots) were taken from Lee et al. (2007). In lower panel, filled and open circles represent the RV measurements for the primary and secondary components, respectively. Earlier observations by Struve (1946) were plotted with open triangles. The dotted line refers to the system velocity of −27.57 km s^{-1} in the upper panel.

Table 2. Binary parameters of XX Cep

Parameter	Primary	Secondary
T_0 (HJD)	2,454,397.1139(87)	
P	2.337357(71)	
K_1 (km s^{-1})	29.6(0.3)	
K_2 (km s^{-1})	196.2(1.8)	
γ (km s^{-1})	−27.57(34)	
a ($R_\odot$)	10.53(10)	
q	0.151(2)	
i (deg)	82.37(2)	
T (K)	7,946	4,483(9)
Ω	4.805(13)	2.106
x_B, y_B	0.790, 0.329	0.851, −0.154
x_V, y_V	0.685, 0.299	0.813, 0.014
x_R, y_R	0.569, 0.278	0.737, 0.116
x_I, y_I	0.464, 0.255	0.641, 0.162
$l/(l_1+l_2)_B$	0.963(2)	0.037
$l/(l_1+l_2)_V$	0.919(4)	0.081
$l/(l_1+l_2)_R$	0.868(5)	0.132
$l/(l_1+l_2)_I$	0.815(5)	0.185
r (pole)	0.2148(6)	0.2146
r (point)	0.2167(6)	0.3167
r (side)	0.2161(6)	0.2232
r (back)	0.2165(6)	0.2551
r (volume)	0.2159	0.2314
Absolute parameters:		
Mass ($M_\odot$)	2.49(6)	0.38(1)
Radius ($R_\odot$)	2.27(2)	2.43(2)
log g (cgs)	4.121(5)	3.240(5)
log L ($L_\odot$)	1.27(5)	0.33(9)
$M_{\rm bol}$ (mag)	1.57(13)	3.91(24)
BC (mag)	0.02	−0.61
M_V (mag)	1.55(13)	4.52(24)
Distance (pc)	329(23)	

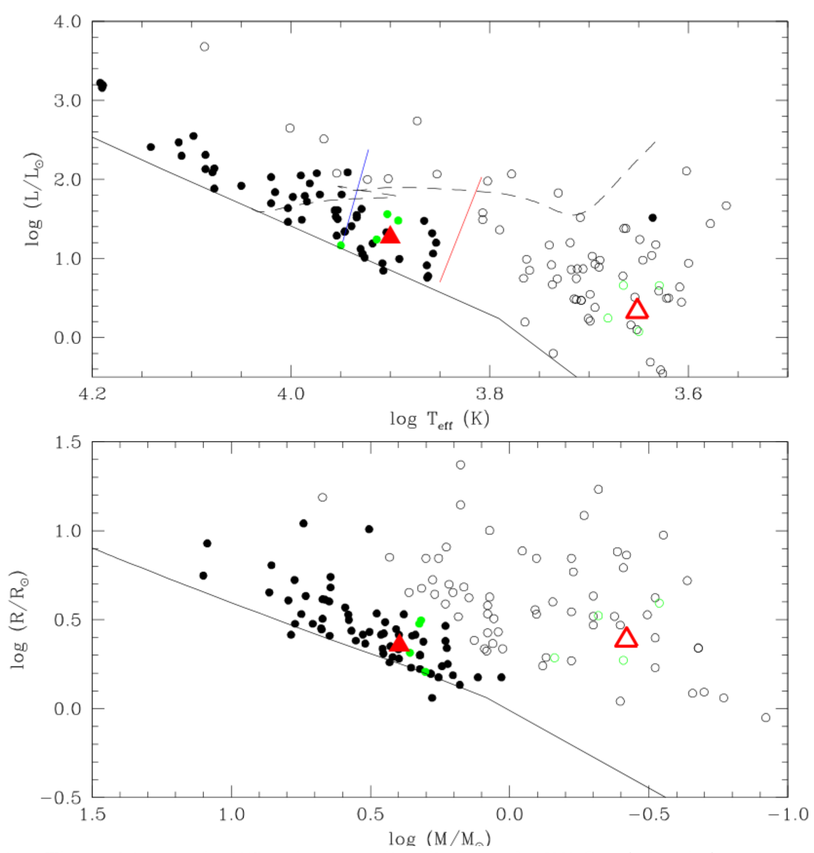

Fig. 4.— The position on the HR and mass-radius diagrams for XX Cep (triangles) and other semi-detached Algol-type eclipsing binaries (circles) by Ibanoğlu et al. (2006). Filled and open symbols refer to the primary and secondary stars, respectively. Green circles indicate well-studied oEA stars with double-lined RV curves. The black solid line displays the ZAMS calculated using equations adopted from Tout et al. (1996) of Z = 0.02. In the upper panel, blue and red lines represent the δ Sct instability strips, and the dashed-line denotes the evolutionary track of a normal main-sequence star having the mass of 2.5 $M_\odot$ and solar abundance.