KIC 6220497: A NEW ALGOL-TYPE ECLIPSING BINARY WITH MULTIPERIODIC PULSATIONS

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ABSTRACT

We present both binarity and pulsation of KIC 6220497 from the *Kepler* observations. The light curve synthesis shows that the eclipsing system is a semi-detached Algol with parameters of q = 0.243 ± 0.001, i = 77.3 ± 0.3 deg, and ΔT = 3,372 ± 58 K, in which the detached primary component fills its Roche lobe by ~87%. A multiple frequency analysis of the eclipse-subtracted light residuals reveals 33 frequencies in the range of 0.75–22.22 d^{-1} with amplitudes between 0.27 and 4.56 mmag. Among these, four are pulsation frequencies in fundamental (f_1, f_5) and p (f_2, f_7) modes, and six are orbital frequency (f_8, f_{31}) and its harmonics (f_6, f_{11}, f_{20}, f_{24}), which can be attributed to tidally excited modes. For the pulsation frequencies, the pulsation constants of 0.16–0.33 d and the period ratios of P_{pul}/P_{orb} = 0.042–0.089 indicate that the primary component is a δ Sct pulsating star and, thus, KIC 6220497 is an oscillating eclipsing Algol (oEA) star. The dominant pulsation period of 0.1174051 ± 0.0000004 d is significantly longer than that expected from empirical relations that link the pulsation period with the orbital period. The surface gravity of log g_1 = 3.78 ± 0.03 is clearly smaller than those of the other oEA stars with similar orbital periods. The pulsation period and the surface gravity of the pulsating primary demonstrate that KIC 6220497 would be the more evolved EB, compared with normal oEA stars. *This result has been accepted for publication in Monthly Notices of the Royal Astronomical Society (MNRAS)*.

Kepler Photometry and Light-Curve Synthesis

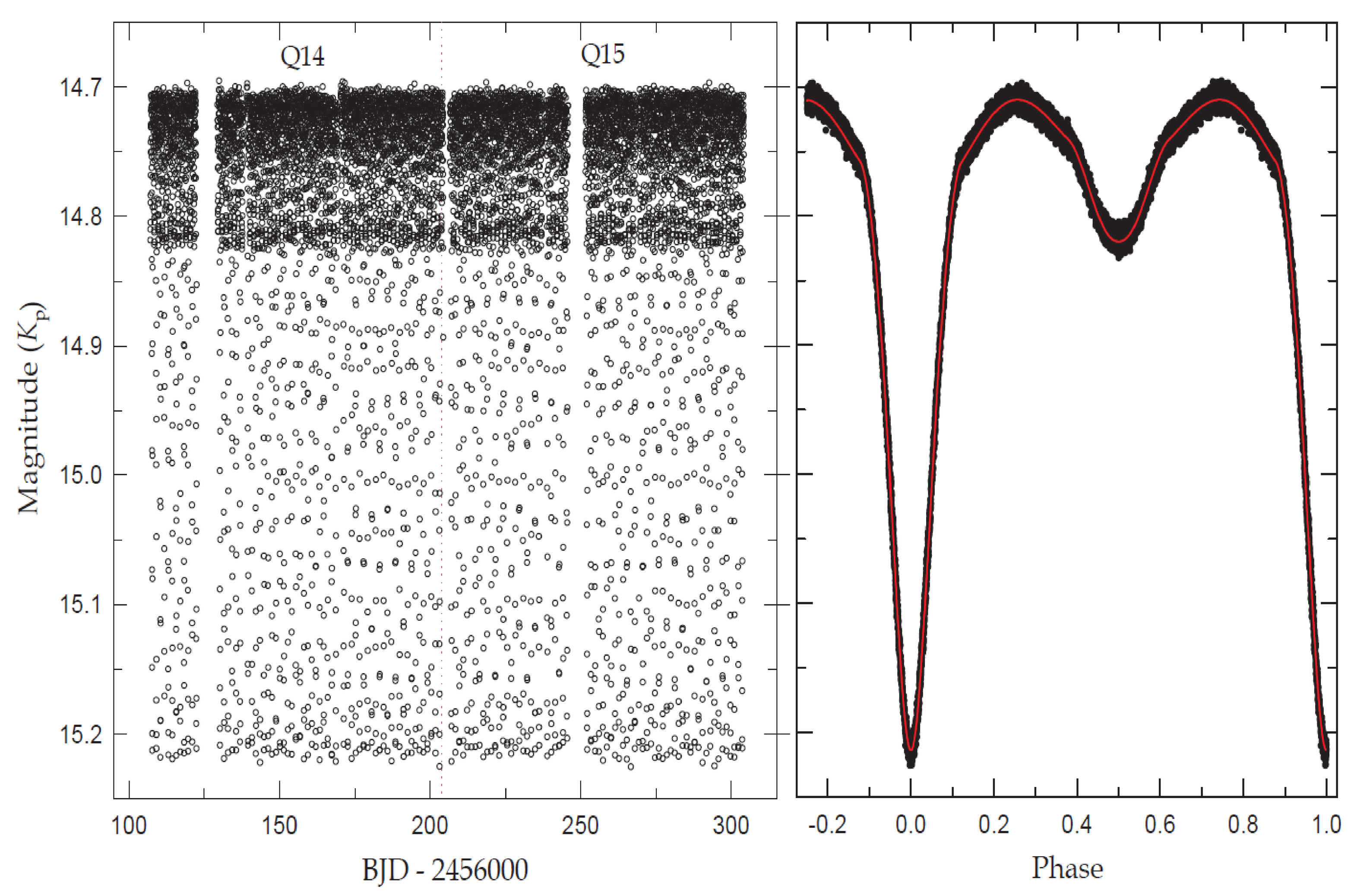

Figure 1. *Kepler* light curve of KIC 6220479 distributed in BJD (left panel) and orbital phase (right panel). The vertical dashed line in the left panel represents the ending time of Quarter 14, and the solid curve in the right panel is the synthetic curve computed from our binary model.

Table 1. Binary parameters of KIC 6220497

Parameter	Primary	Secondary
T_0 (BJD)	2,456,204.39619(2)	
P (day)	1.3231670(6)	
q	0.243(1)	
i (deg)	77.3(3)	
T (K)	7,279(54)	3,907(22)
Ω	2.689(7)	2.336
A	1.0	0.5
g	1.0	0.32
X, Y	0.640, 0.259	0.621, 0.150
x, y	0.598, 0.258	0.750, 0.026
$L/(L_1+L_2)$	0.978(2)	0.022
r (pole)	0.4058(11)	0.2462(6)
r (point)	0.4477(18)	0.3593(8)
r (side)	0.4249(14)	0.2562(6)
r (back)	0.4355(15)	0.2888(6)
r (volume)	0.4223(13)	0.2646(6)
$\sum W(O-C)^2$	0.0023	
Absolute parameters:		
M ($M_\odot$)	1.60(8)	0.39(2)
R ($R_\odot$)	2.69(6)	1.69(4)
log g (cgs)	3.78(3)	3.57(3)
L ($L_\odot$)	18(2)	0.6(1)
M_{bol} (mag)	1.6(1)	5.3(2)

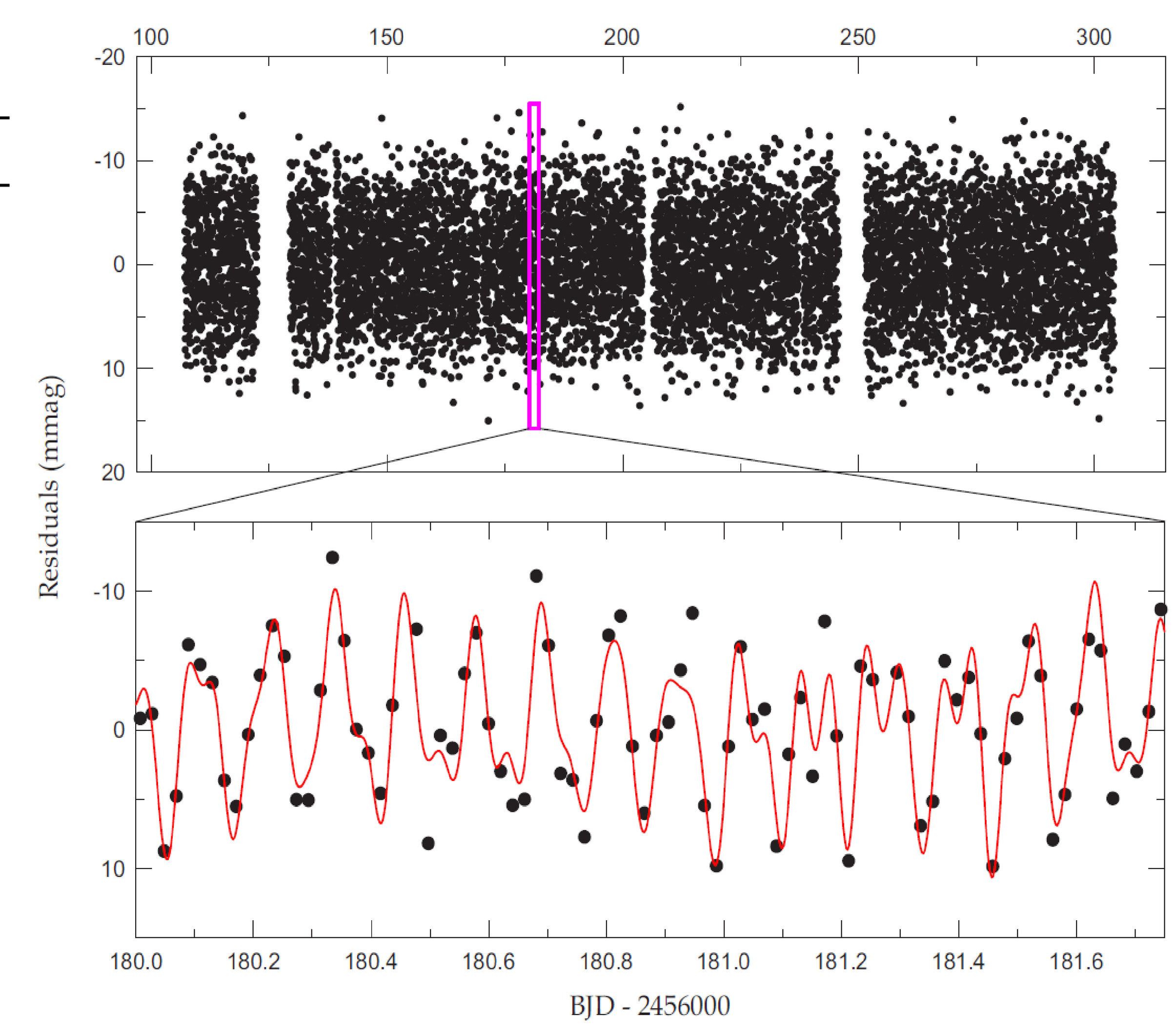

Figure 2. Light residuals after subtracting the binarity effects from the observed *Kepler* data. The lower panel presents a short section of the residuals marked using the inset box of the upper panel. The synthetic curve was computed from the 33-frequency fit to the data.

Pulsational Characteristics & Discussion

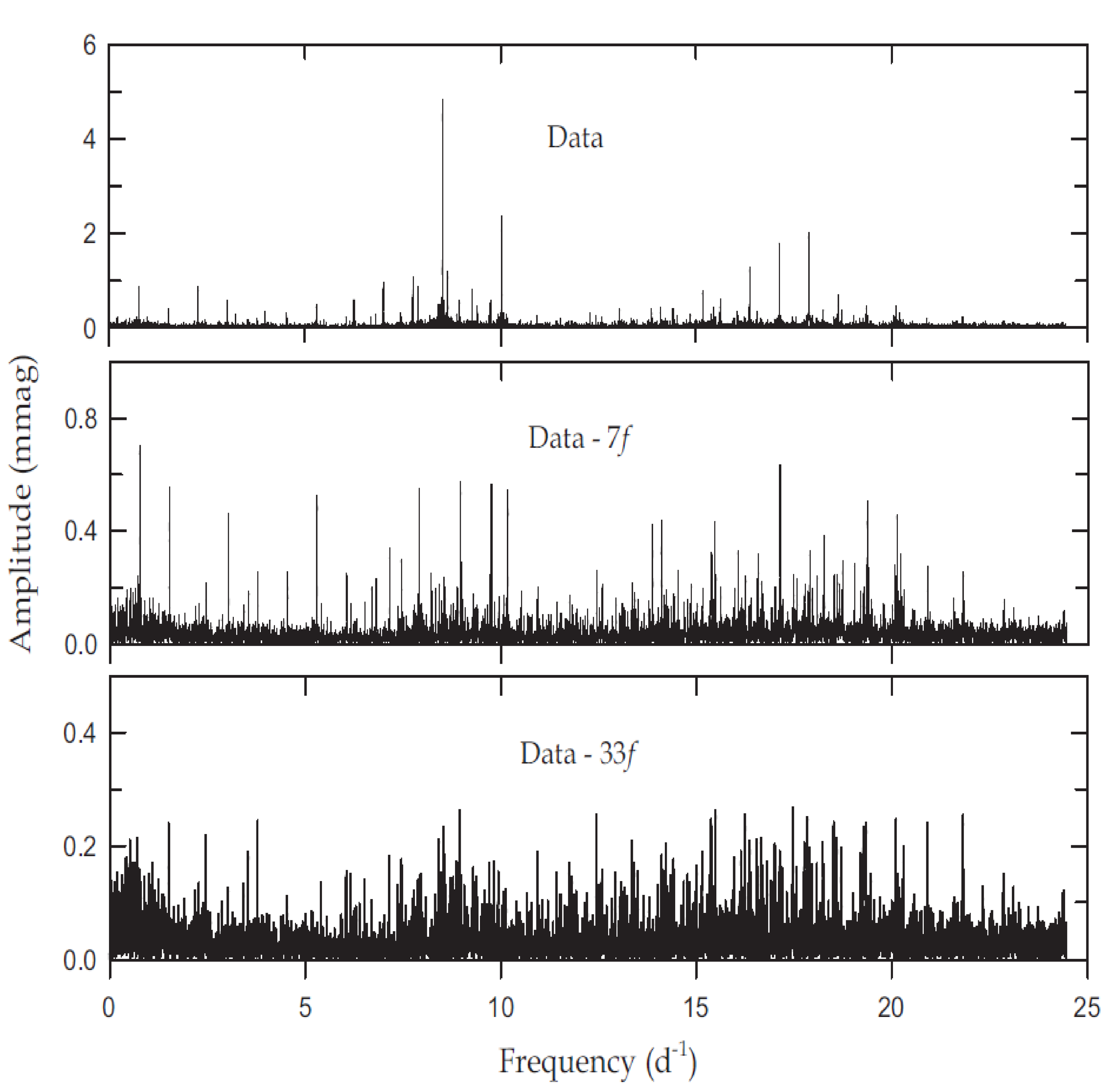

Figure 3. Amplitude spectra before (top panel) and after pre-whitening the first 7 frequencies (middle panel) and all 33 frequencies (bottom panel) from the PERIOD04 program. The frequency analysis was applied to the entire *Kepler* data between orbital phases 0.12 and 0.88 except for the times of the primary eclipses.

Table 2. Multiple Frequency Analysis of KIC 6220497[a]

	Frequency (day^{-1})	Amplitude (mmag)	Phase (rad)	S/N[b]	Remark
f_1	8.51752±0.00003	4.56±0.15	6.24±0.10	52.39	
f_2	17.88717±0.00006	2.19±0.13	0.77±0.18	28.07	
f_3	16.37582±0.00009	1.56±0.13	4.78±0.25	20.25	$f_2 - 2f_{orb}$
f_4	10.02912±0.00010	1.41±0.14	2.51±0.30	16.79	$f_1 + 2f_{orb}$
f_5	8.65383±0.00014	1.11±0.15	2.04±0.39	12.75	
f_6	2.26728±0.00015	0.62±0.09	5.71±0.43	11.59	$3f_{orb}$
f_7	15.17161±0.00014	0.81±0.11	5.44±0.41	12.16	
f_8	0.75567±0.00014	0.78±0.11	3.52±0.40	12.60	f_{orb}
f_9	17.13175±0.00017	0.81±0.13	2.53±0.48	10.34	$f_2 - f_{orb}$
f_{10}	8.95666±0.00025	0.60±0.15	4.52±0.72	6.96	
f_{11}	5.29073±0.00014	0.58±0.08	1.02±0.40	12.67	$7f_{orb}$
f_{12}	9.73721±0.00026	0.56±0.14	0.40±0.75	6.68	$3f_{10} - f_2 + f_{orb}$
f_{13}	9.75701±0.00026	0.56±0.14	2.62±0.75	6.65	$3f_1 - 2f_5 + 2f_{orb}$
f_{14}	7.89790±0.00029	0.52±0.15	3.94±0.83	6.05	$f_5 - f_{orb}$
f_{15}	19.35892±0.00030	0.40±0.12	1.45±0.87	5.77	
f_{16}	10.16518±0.00030	0.49±0.14	4.76±0.86	5.80	$f_5 + 2f_{orb}$
f_{17}	14.09534±0.00023	0.44±0.10	1.38±0.67	7.43	
f_{18}	15.46378±0.00029	0.44±0.13	3.94±0.83	6.04	
f_{19}	13.87196±0.00023	0.42±0.09	3.35±0.66	7.57	
f_{20}	3.02371±0.00019	0.44±0.09	3.39±0.56	8.94	$4f_{orb}$
f_{21}	18.26412±0.00033	0.40±0.13	3.16±0.95	5.28	$7f_{10} - 2f_2 - f_5$
f_{22}	16.05471±0.00040	0.32±0.13	0.39±1.17	4.28	
f_{23}	17.88336±0.00037	0.37±0.13	3.48±1.06	4.73	
f_{24}	6.80183±0.00037	0.35±0.13	6.22±1.06	4.73	$9f_{orb}$
f_{25}	20.11434±0.00032	0.34±0.11	5.61±0.92	5.48	
f_{26}	7.43718±0.00042	0.32±0.13	1.67±1.23	4.09	$f_{10} - 2f_{orb}$
f_{27}	16.57356±0.00042	0.32±0.13	5.63±1.23	4.09	
f_{28}	18.73168±0.00042	0.30±0.13	6.26±1.23	4.09	$2f_2 - 2f_1$
f_{29}	19.03705±0.00040	0.30±0.12	2.67±1.16	4.32	
f_{30}	20.21511±0.00035	0.30±0.10	5.89±1.02	4.93	
f_{31}	0.75212±0.00036	0.30±0.11	0.67±1.04	4.80	f_{orb}
f_{32}	20.06306±0.00039	0.27±0.11	6.26±1.13	4.43	$2f_1 + 4f_{orb}$
f_{33}	14.52484±0.00039	0.27±0.10	4.58±1.13	4.42	$f_2 - f_5 + 7f_{orb}$

[a] Frequencies are listed in order of detection.
[b] The noise was calculated in a range of 5 d^{-1} around each frequency.

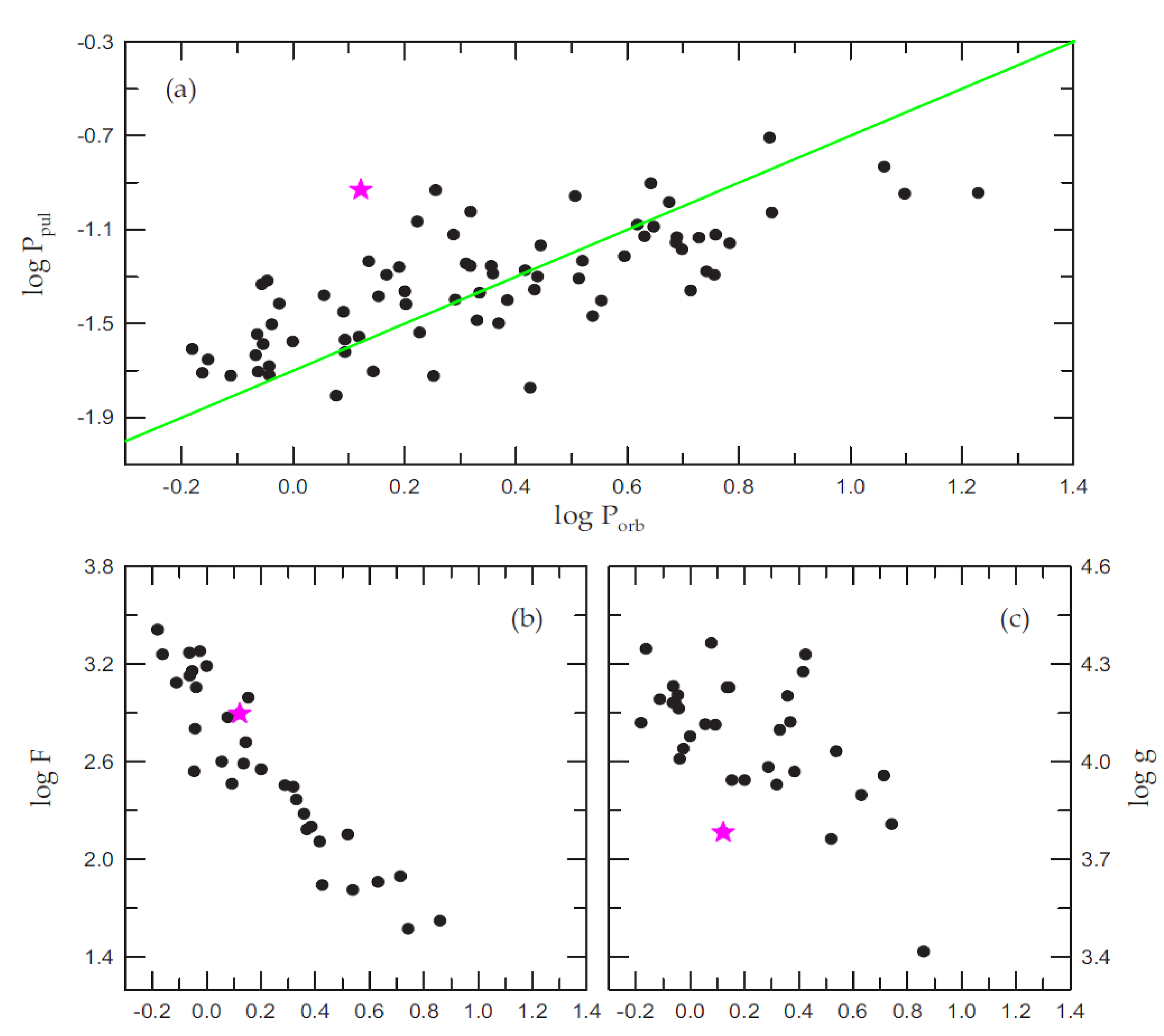

Figure 4. Plots of (a) pulsation periods log P_{pul}, (b) the gravitational forces log F, and (c) surface gravities log g against the orbital periods log P_{orb} for oEA stars. The star symbols denote the parameters of KIC 6220497, and the solid line in the upper panel represents the relation of log P_{pul} = log P_{orb} − 1.70 given by Zhang, Luo & Fu (2003).