National Astronomical Research Institute of Thailand (Public Organization)
Ministry of Science and Technology of Thailand

中國科學院雲南天文台
YUNNAN OBSERVATORIES,CHINESE ACADEMY OF SCIENCES

Photometric Observations on Extreme Mass Ratio Overcontact Binary (EMROB)

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Outline

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2. Observing Facilities at NARIT and YNOs

3. Results of EMROB

4. Summary

Introduction

1. Primary sources in providing fundamental stellar parameters;
2. Progenitors of FK Com type stars, blue stragglers;
3. Tertiary components around binary systems (circumbinary planets, black holes);
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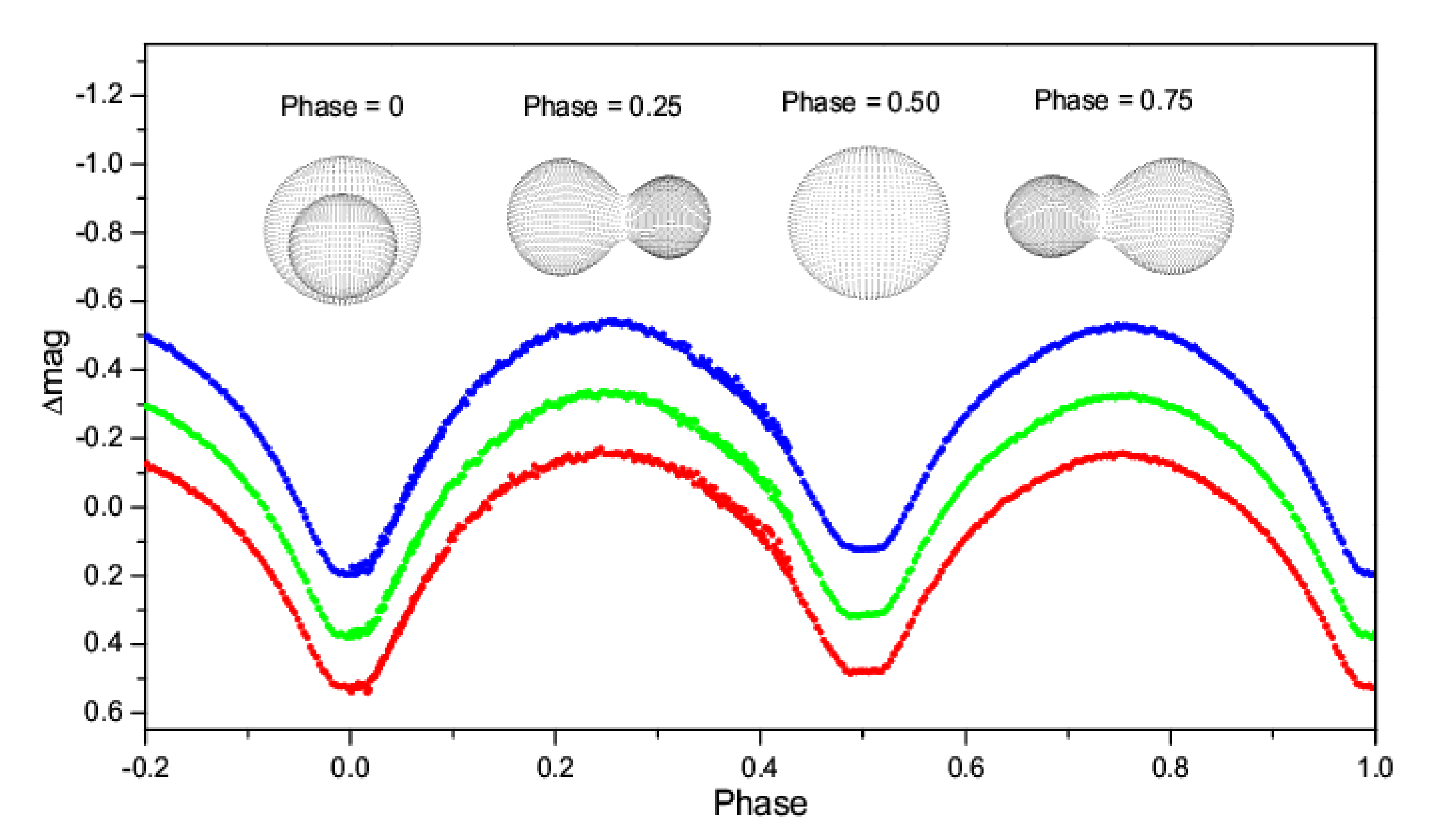
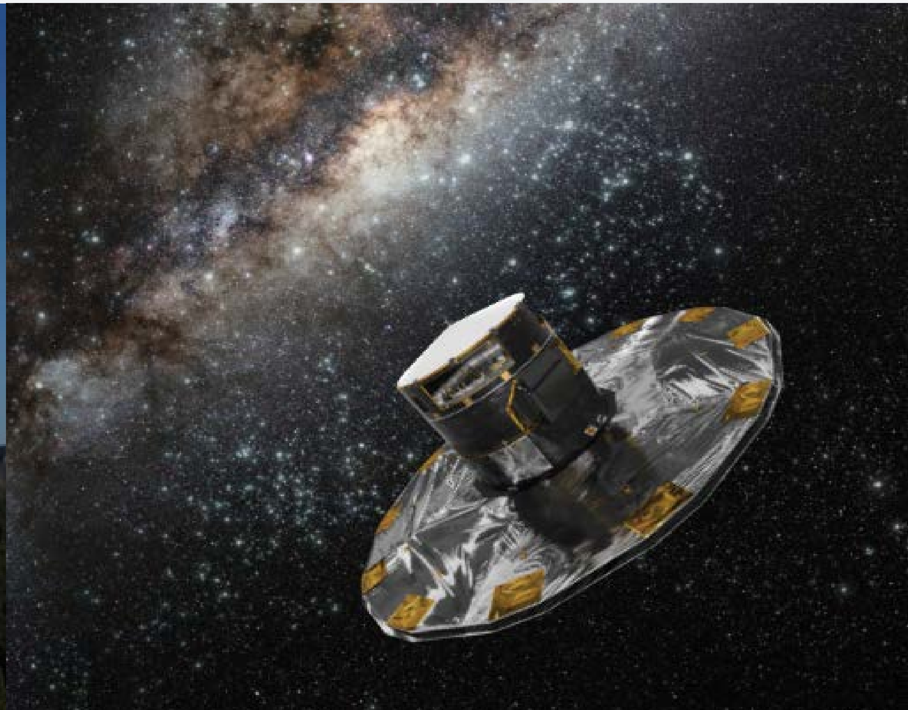


Photometric: Optical Gravitational Lensing Experiment (OGLE),
All Sky Automated Survey (ASAS) ,
Wide Angle Search for Planets (SuperWASP),
Kepler ,
Transiting Exoplanet Survey Satellite (TESS)

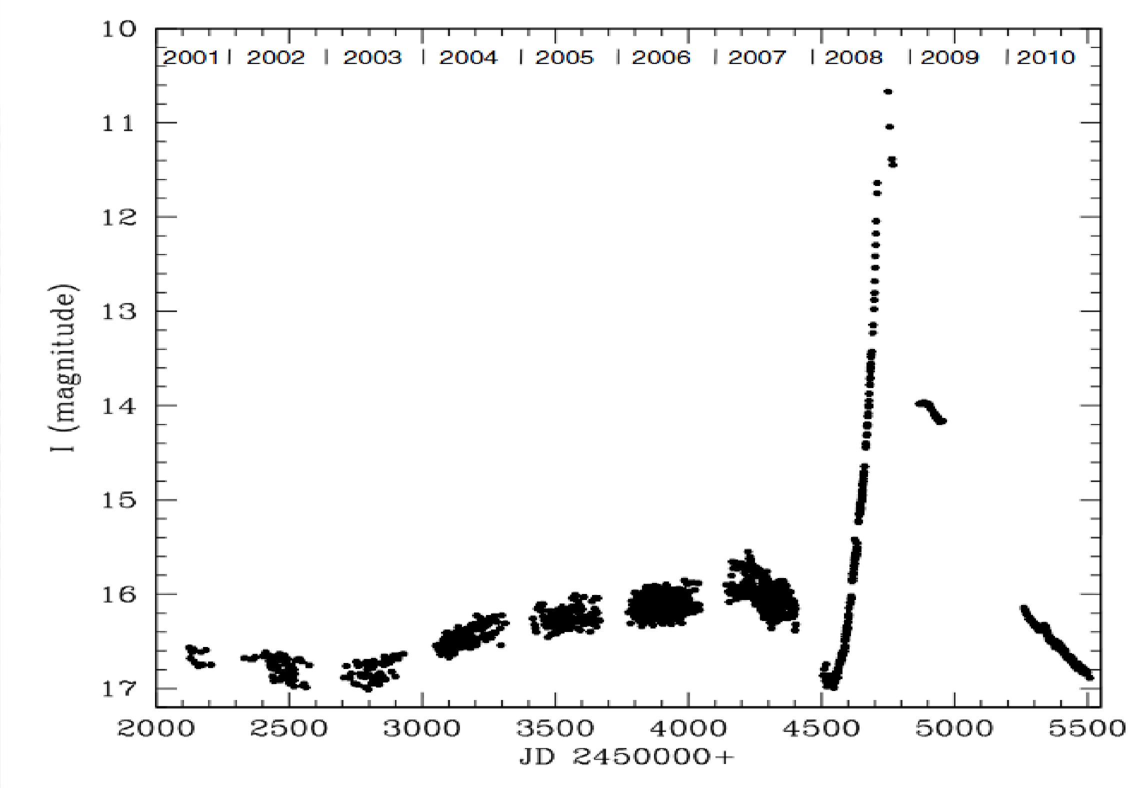
Spectroscopic: Sloan Digital Sky Survey(SDSS),
Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST),
Gaia mission.



Stellar Merger

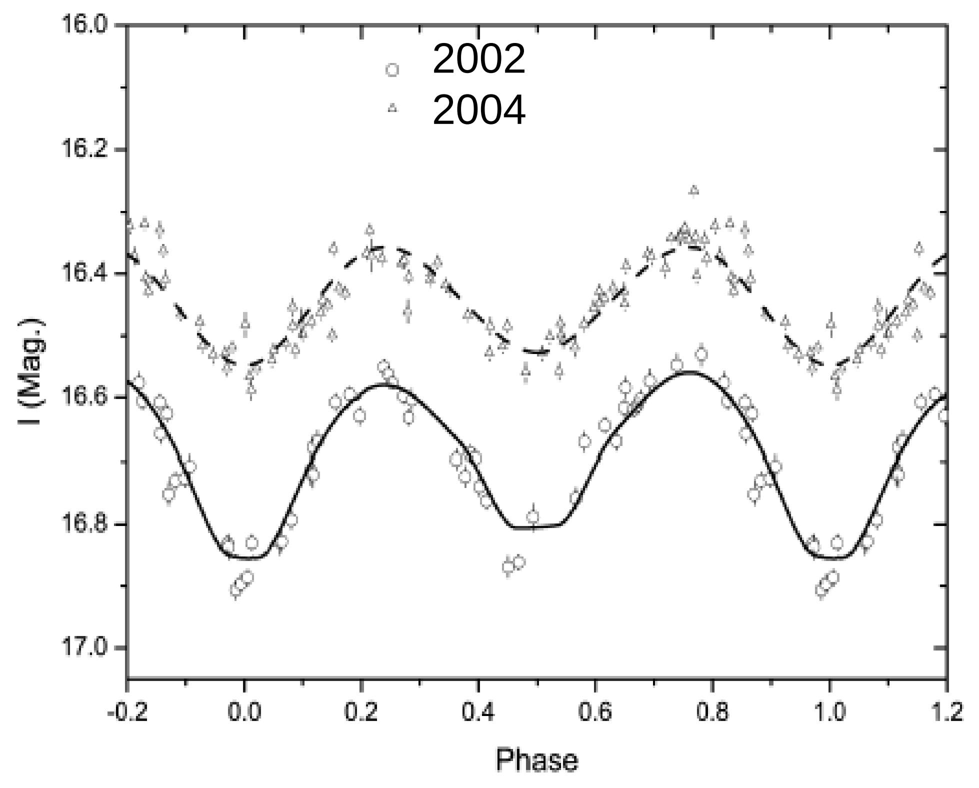
Stellar mergers are estimated to be common events in the Galaxy. Theoretical models predict that a contact binary system will merge around q ~ 0.07–0.09 (Rasio & Shapiro 1995; Li & Zhang 2006; Arbutina 2007, 2012). The minimum mass ratio can even fall up to q = 0.05 and it depends on the mass and structure of primary star. So far, only a handful number of these transients have been noted in the Milky Way: V4332 Sgr (Hayashi et al. 1994), V838 Mon (Brown et al. 2002), V1309 Sco (Nakano et al. 2008), and OGLE-2002-BLG-360 (Tylenda et al. 2013). And the best studied stellar merger case to date is V1309 Sco.

Eruption of V1309 Sco in 2008



Light curve of V1309 Sco

Tylenda et al. (2011)



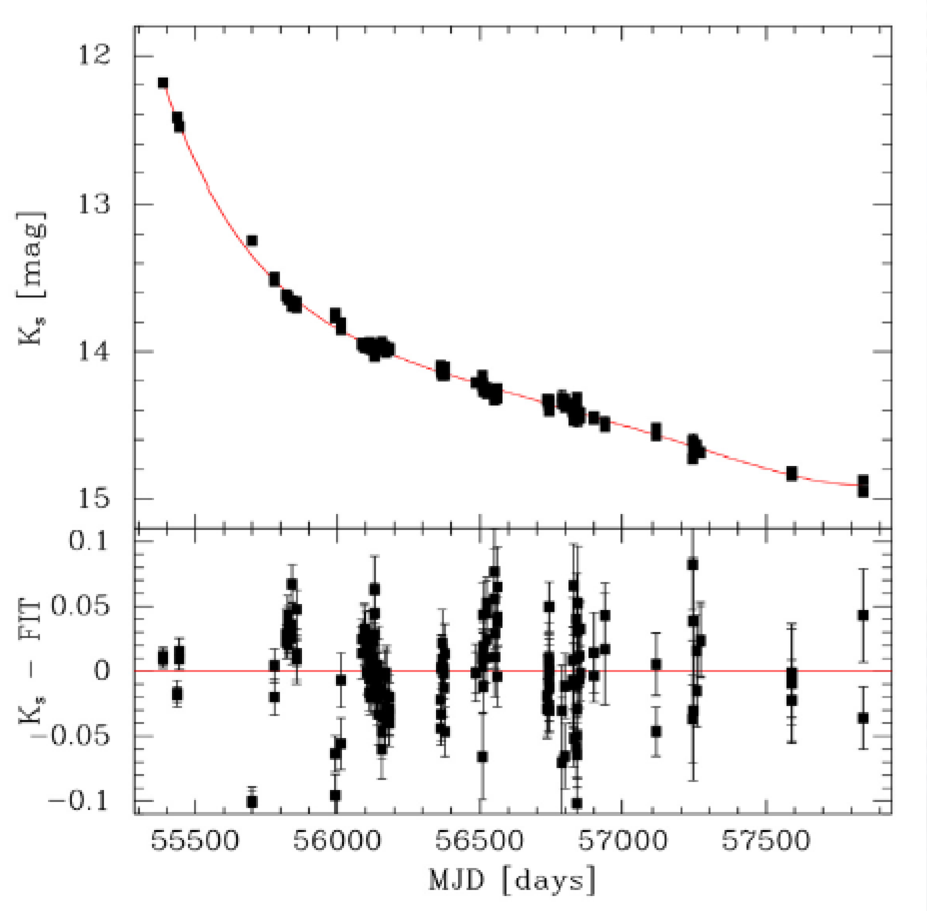
2002: q = 0.094, f = 89%

Zhu et al. (2016)

V1309 Sco: a Blue Straggler in the making ?

V1309 Sco has changed its color at a relatively high rate, going from **(J-Ks) = 1.40 mag in 2010 to (J-Ks) = 0.42 mag in 2015**. This significant color change in a relatively short period of time shows that V1309 Sco was getting bluer and hotter with time, behaving as a blue straggler star.

Reasonable equilibrium in this stellar merger is being reached in about 9 years after the outburst. V1309 Sco has settled into a nearly constant magnitude, resembling a normal blue star. The asymptotic blue color of V1309 Sco as the resultant of a stellar merger suggests that the object is a blue straggler in the making, as theoretically predicted.



Ferreira et al. (2019)

Observing Facilities at NARIT and YNOs

Thai National Observatories (TNO) 2.4m telescope

TNO 2.4m telescope:

1. 4k × 4k CCD camera;
2. MRES (medium resolution spectrograph)
3. ULTRASPEC (high-speed CCD camera; 200 frames per second)

Another 1m ongoing!!!

NARIT’s Network of Optical Telescopes

∅ 2.4 meters

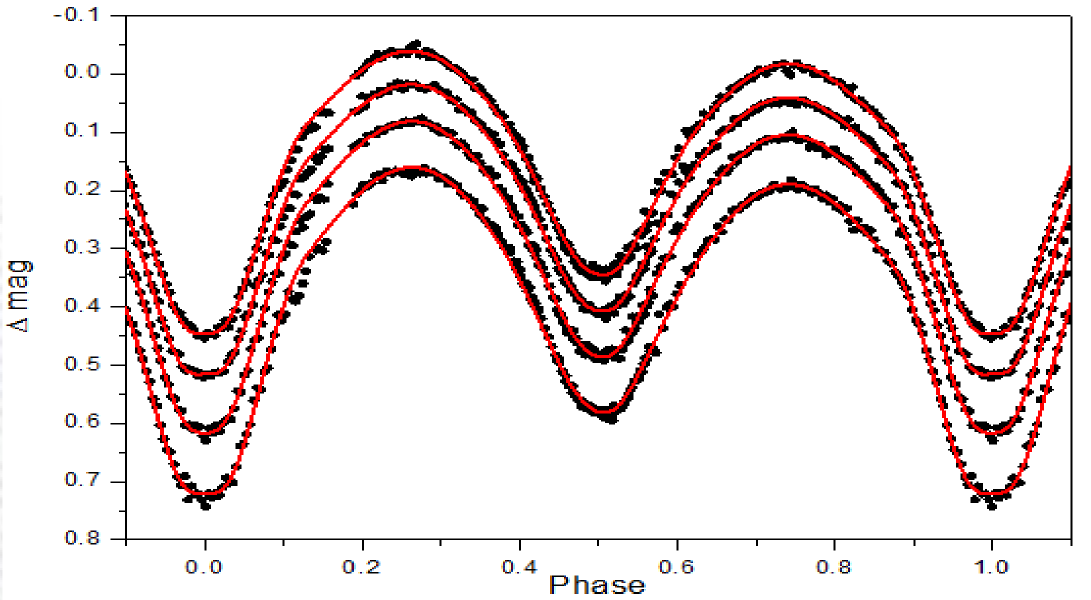
∅ 0.7 meters

Observing Facilities at YNOs

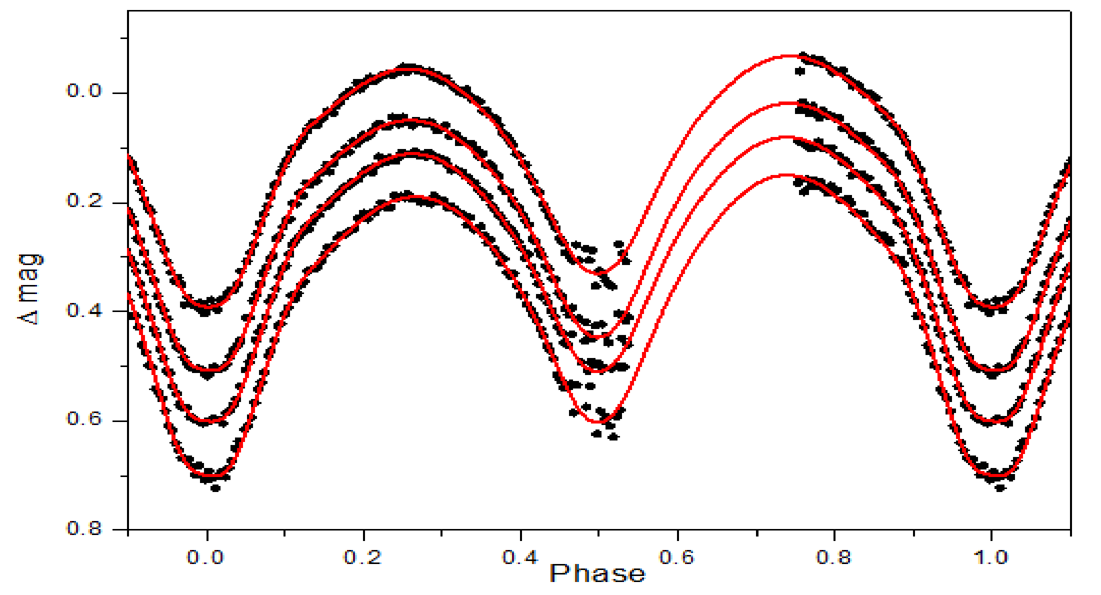
Results of EMROB

The W-subtype system PZ UMa

April. 2016
TNO 2.4m



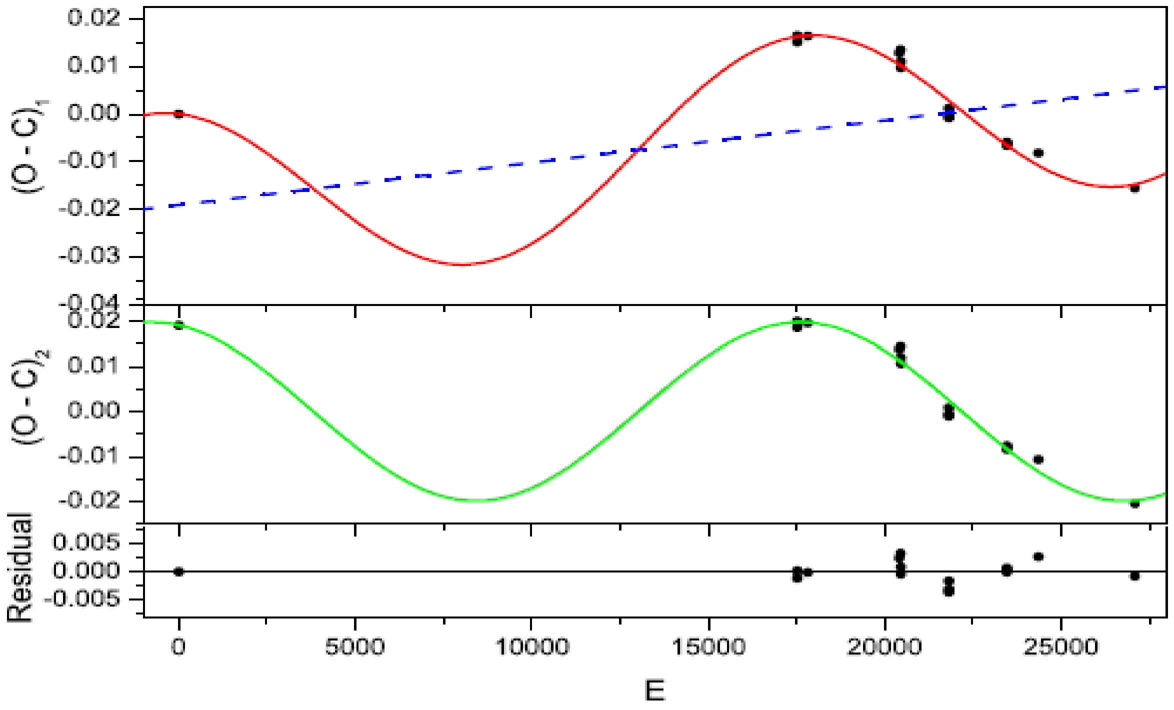
Dec. 2016
YNOs 1m



Parameters	TNO	YNOs
T_1 (K)	5430 (fixed)	5430 (fixed)
q (M_2/M_1)	5.62(±0.16)	5.13(±0.24)
i (°)	74.8(±0.6)	74.7(±0.7)
$\Omega_1 = \Omega_2$	9.67(±0.18)	9.17(±0.28)
T_2 (K)	4972(±18)	5137(±49)
ΔT (K)	458	293
T_2/T_1	0.916(±0.003)	0.946(±0.009)
$L_1/(L_1+L_2)$		
$L_1/(L_1+L_2)$ (B)	0.292(±0.001)	0.256(±0.001)
$L_1/(L_1+L_2)$ (V)	0.265(±0.001)	0.240(±0.001)
$L_1/(L_1+L_2)$ (R_C)	0.248(±0.001)	0.230(±0.001)
$L_1/(L_1+L_2)$ (I_C)	0.237(±0.001)	0.224(±0.001)
r_1 (pole)	0.238(±0.002)	0.239(±0.003)
r_1 (side)	0.249(±0.002)	0.250(±0.003)
r_1 (back)	0.295(±0.004)	0.290(±0.004)
r_2 (pole)	0.507(±0.009)	0.497(±0.015)
r_2 (side)	0.559(±0.015)	0.544(±0.022)
r_2 (back)	0.584(±0.019)	0.569(±0.028)
f	38.8%(±28.2%)	24.2%(±43.7%)
θ (°)	161.3(±2.1)	5.4(±1.0)
ψ (°)	281.9(±9.3)	105.5(±14.0)
r (rad)	0.69 (fixed)	0.69 (fixed)
T_f	0.81 (fixed)	0.81 (fixed)
$\Sigma\omega(O-C)^2$	0.00355	0.00406

P = 0.2627 d (6.30 h), Mag. Range = 12.537 - 13.074 R1

The O – C curve of PZ UMa



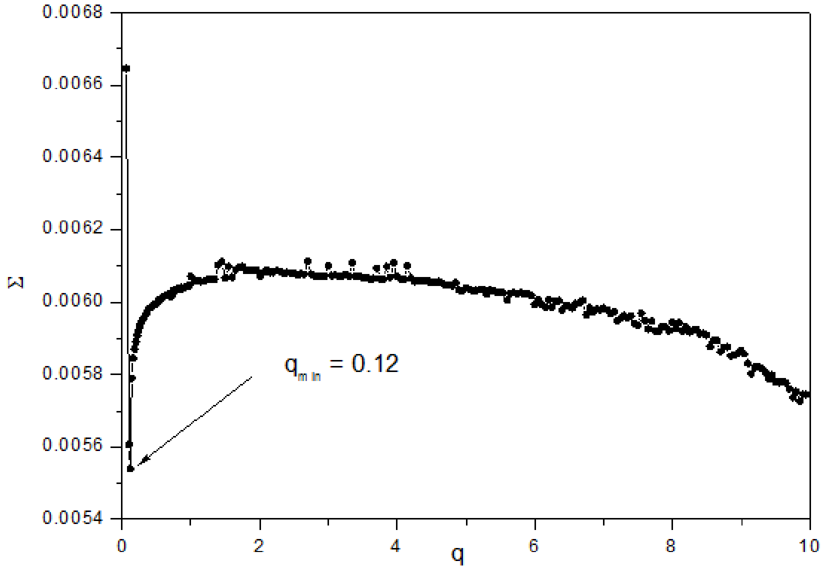
$$\begin{aligned}\mathrm{Min.I} = {} & 2451337.6950(\pm 0.0004) \\ & + 0.26267489(\pm 0.00000002) \times E \\ & \times 0.0198(\pm 0.0002)\sin[0.0196^{\circ}(\pm 0.0002) \times E \\ & + 105.0^{\circ}(\pm 0.6)]\end{aligned}$$

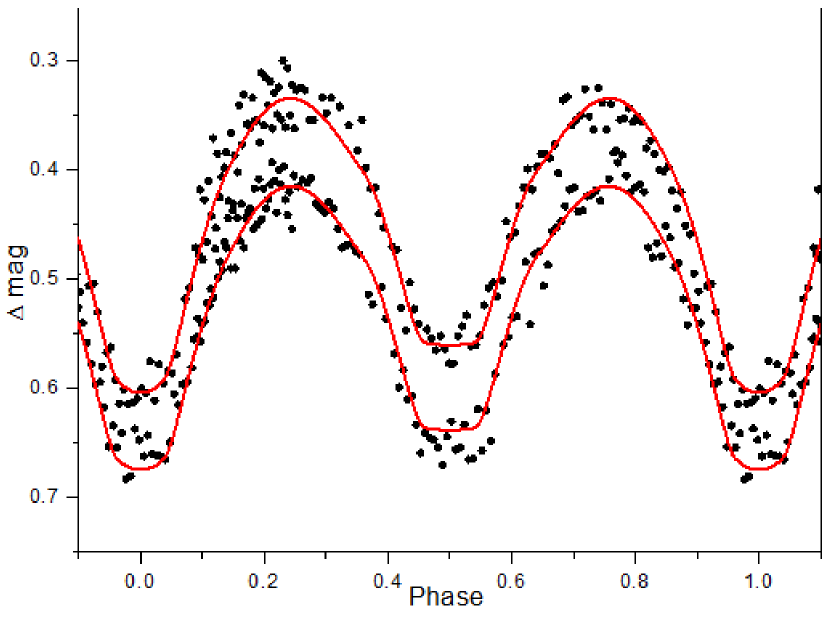
Parameters	Primary (star1)	Secondary (star 2)
M	$0.14(\pm 0.01)M_{\odot}$	$0.77(\pm 0.02)M_{\odot}$
R	$0.43(\pm 0.01)R_{\odot}$	$0.92(\pm 0.01)R_{\odot}$
L	$0.15(\pm 0.03)L_{\odot}$	$0.46(\pm 0.02)L_{\odot}$

P3 = 13.22 yr
M3min = 0.84 Msun

The tertiary component may be a compact object !

The A-subtype system CSS_J135012.1+272259

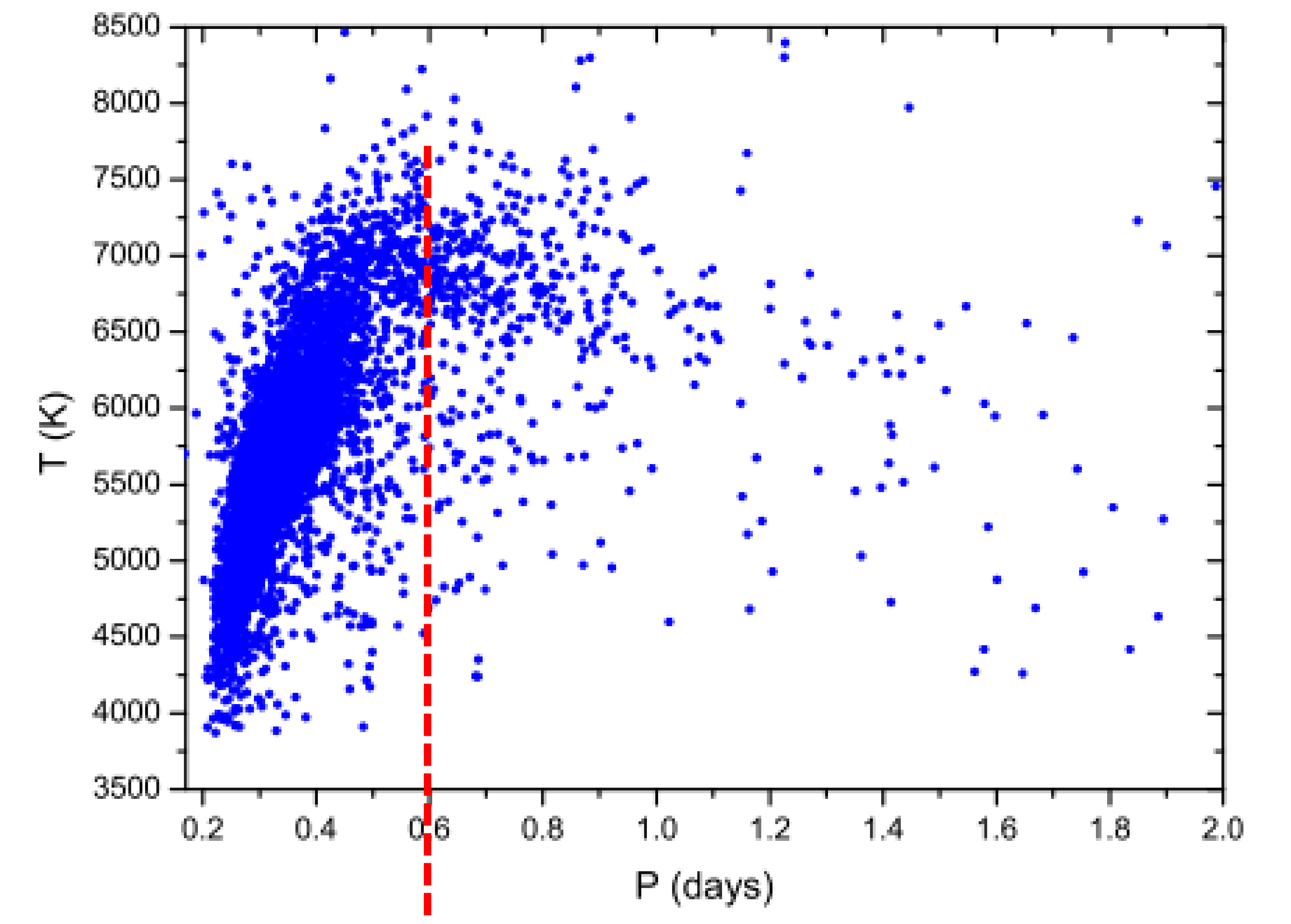




Parameters	Values without l_3	Values with l_3
$T_1(K)$	6137(fixed)	6137(fixed)
q (M_2/M_1)	0.114(±0.004)	0.147(±0.011)
$i(°)$	75.9(±1.3)	79.1(±1.6)
$\Omega_1 = \Omega_2$	1.98(±0.01)	2.06(±0.03)
$T_2(K)$	5838(±43)	5891(±55)
$\Delta T(K)$	299	246
T_2/T_1	0.951(±0.007)	0.960(±0.009)
$L_1/(L_1+L_2)$ (R_c)	0.8931(±0.0004)	0.863(±0.009)
$L_1/(L_1+L_2)$ (I_c)	0.8905(±0.0004)	0.860(±0.009)
$L_1/(L_1+L_2+L_3)$ (R_c)		0.705(±0.036)
$L_1/(L_1+L_2+L_3)$ (I_c)		0.702(±0.038)
$L_3/(L_1+L_2+L_3)$ (R_c)		0.183(±0.039)
$L_3/(L_1+L_2+L_3)$ (I_c)		0.184(±0.041)
$r_1(pole)$	0.530(±0.003)	0.518(±0.005)
$r_1(side)$	0.590(±0.005)	0.572(±0.008)
$r_1(back)$	0.610(±0.005)	0.596(±0.008)
$r_2(pole)$	0.202(±0.015)	0.223(±0.032)
$r_2(side)$	0.211(±0.018)	0.234(±0.039)
$r_2(back)$	0.247(±0.040)	0.278(±0.092)
f	18.6 %(±20.1 %)	34.0 %(±30.8 %)
$\Sigma\omega(O-C)^2$	0.0051	0.0045

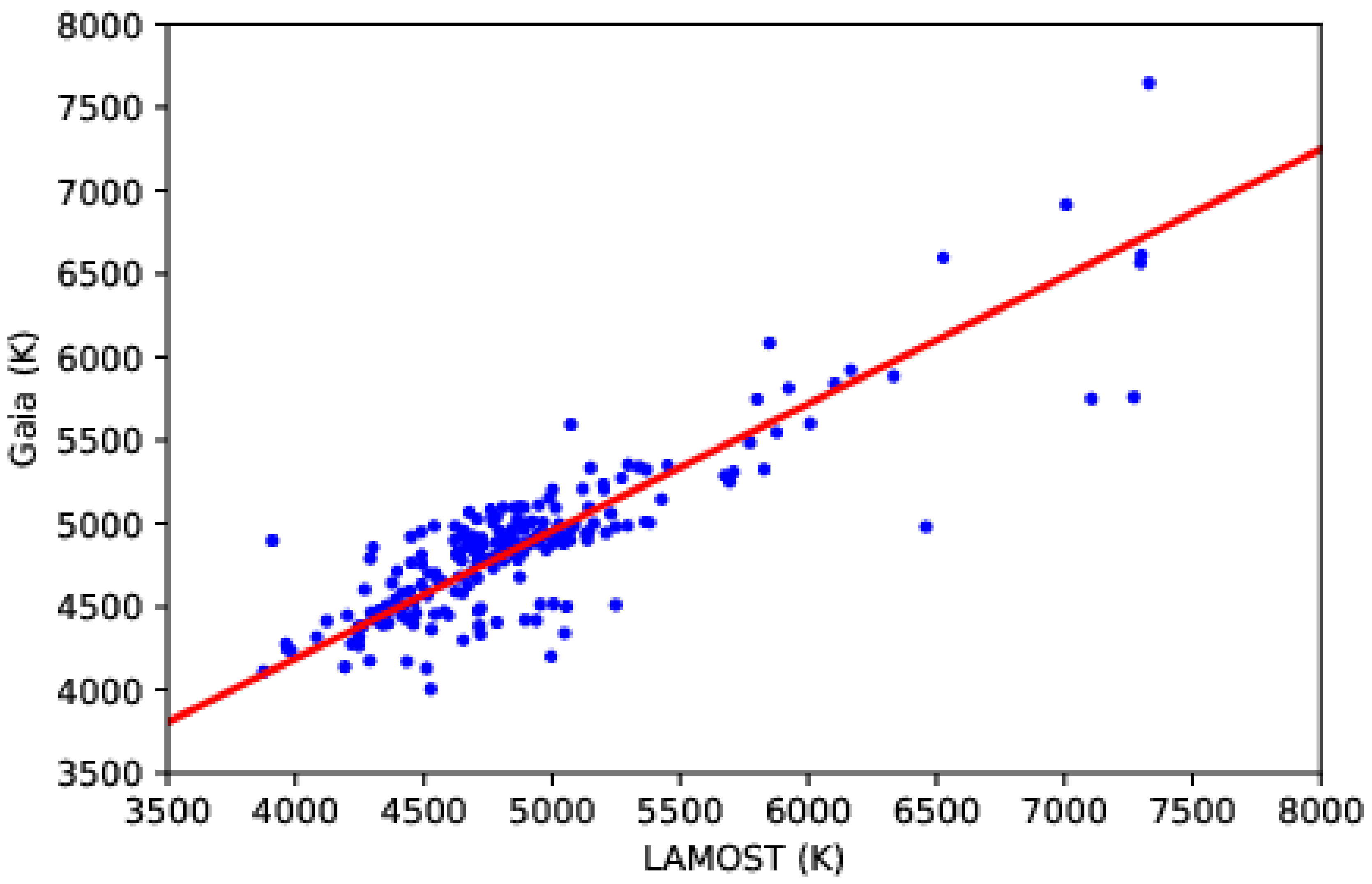
P = 0.232465 d (5.5792 h), Mag. Range = 16.60 (0.22) CV

Determination of mean surface temperature (Teff)



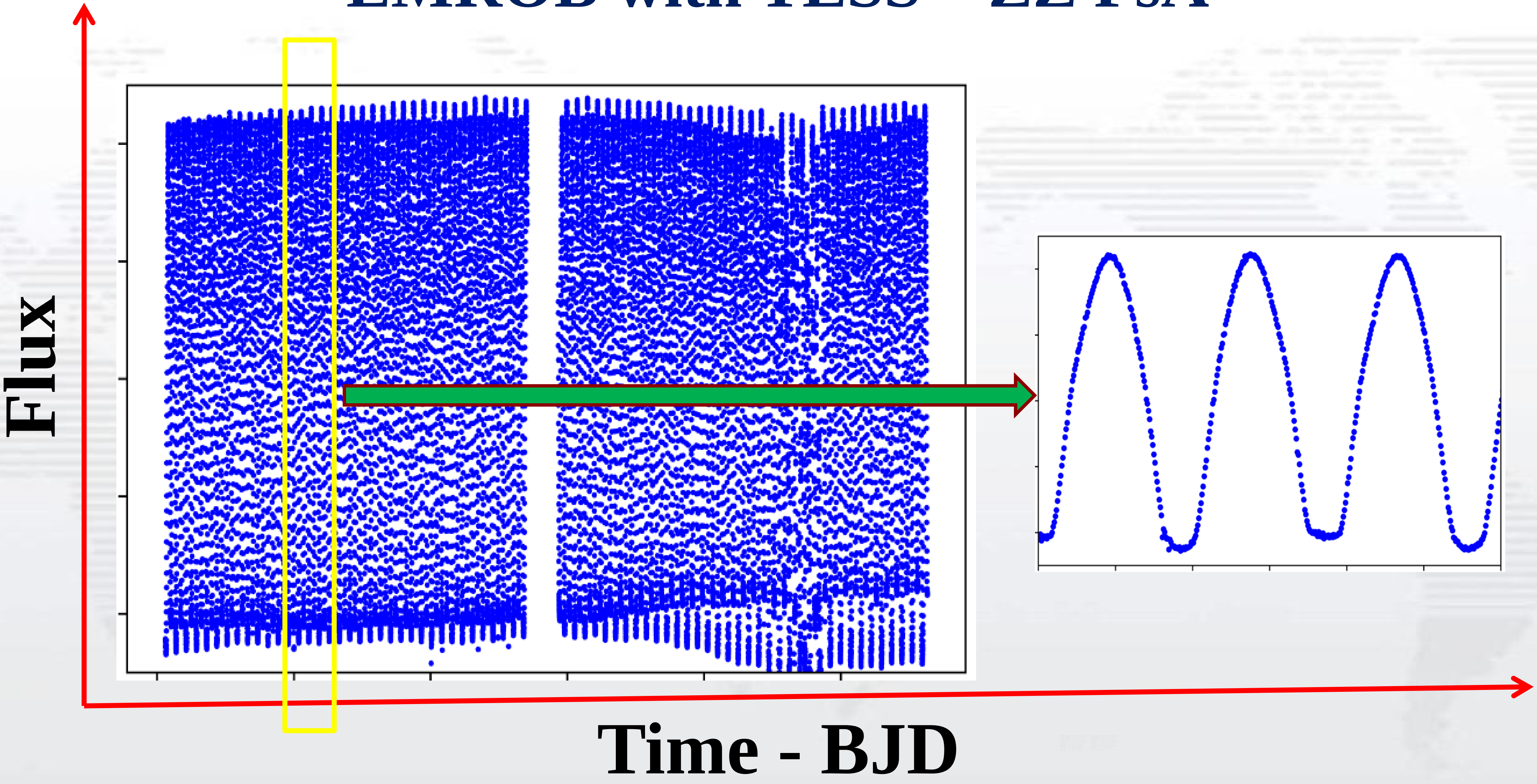
The correlation between the orbital period and the effect temperature for EWs observed by LAMOST.

LAMOST vs Gaia

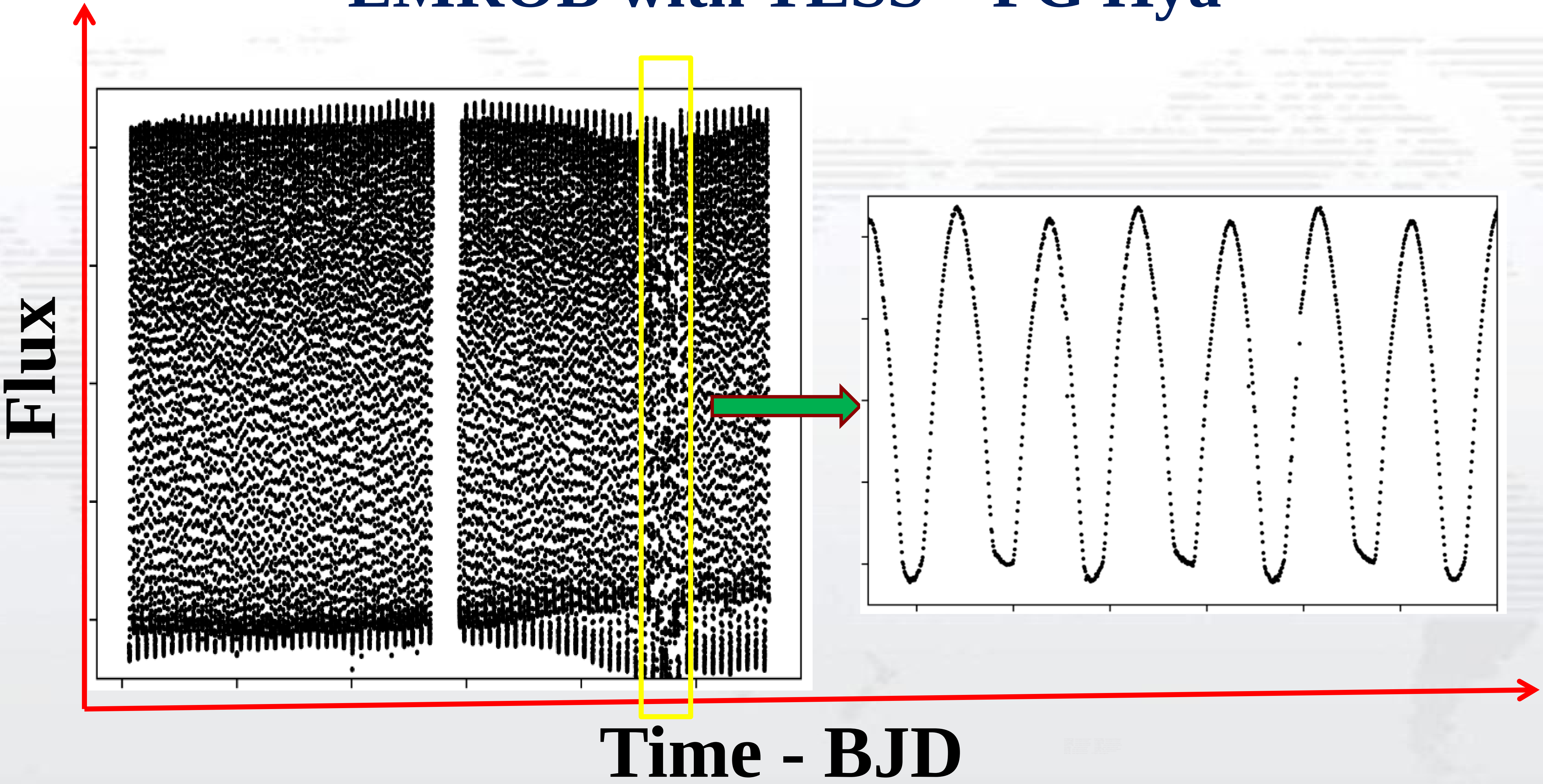


Star	Spec.	Period	q_ph	q_sp	f	i	T1	T2
V857 Her	F6	0.3822	0.065		83.8	85.3	8300	8513
ASAS J083241+2332.4		0.3113	0.068		69.2	82.7	6300	6672
SX Crv		0.3166	0.072		27.0	61.2	6340	6160
V53		0.3084	0.078		69.1	74.4	7415	6611
AW UMa	F2V	0.4387	0.080	0.099	84.6	78.3	7175	7022
NSV 13890(ZZ PsA)		0.3739	0.080		90.0	76.2	6510	6426
V870 Ara	F8	0.3997	0.082	0.082	96.4	70.0	5860	6210
AW CrB		0.3609	0.101		75.0	82.1	6700	6808
DN Boo		0.4476	0.103		64.0	60.0	6095	6071
ASAS J082243+1927		0.2800	0.106		72.0	75.6	5960	6078
V1191Cyg	F6V	0.3134	0.107	0.107	68.6	80.4	6500	6626
CK Boo	F7/8V	0.3552	0.109	0.111	65.0	64.9	6200	6291
GR Vir	F7/8V	0.3278	0.112	0.112	78.6	83.4	6300	6163
FG Hya	G2V	0.3278	0.112	0.112	85.6	82.3	5900	6012
GSC 5909-189(AL Lep)	G0	0.4486	0.120		62.7	73.8	6008	5907
V776 Cas	F2V	0.4404	0.138	0.130	77.0	52.9	6700	6725
V345 Gem	F7V	0.2748	0.142	0.142	73.3	72.9	6115	6365
V410 Aur	G0/2V	0.3664	0.143	0.144	52.4	78.6	6040	5915
V710 Mon		0.4052	0.143		62.7	79.9	6145	6294
DZ Psc	F7V	0.3661	0.145	0.136	79.0	80.5	6210	6287
HV Aqr		0.3734	0.145		56.9	79.2	6460	6669
XY LMi		0.4369	0.148		74.1	81.0	6144	6093
EM Psc		0.3440	0.149		95.3	88.6	5300	4987
TYC 4157-683-1		0.3961	0.150		76.3	79.7	6037	5888

EMROB with TESS – ZZ PsA



EMROB with TESS – FG Hya



Summary

The merger event of V1309 Sco has confirmed that a blue straggler is making in the center and its progenitor star is an extreme mass ratio overcontact binary system. In our sample, there are 25 targets with mass ratio lower than $q = 0.15$, which are supposed to merge in the near future. And 7 targets (V857 Her, ASAS J083241+2332.4, SX Crv, V53, AW UMa, NSV 13890, V870 Ara) with mass ratio lower than 0.09, which may merge recently. It is necessary to monitor these targets continuously from now on.

Welcome to visit NARIT and YNOs !

Thank   you !

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