Photometric study of 61 total eclipsing contact binaries from ASAS, OGLE, HATNet, AST3 and TESS databases

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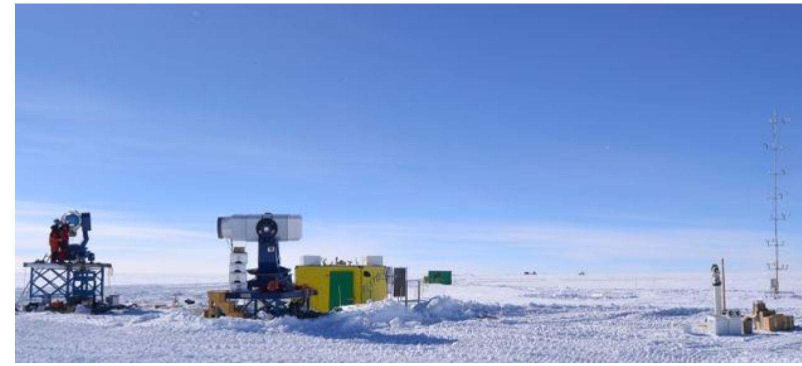
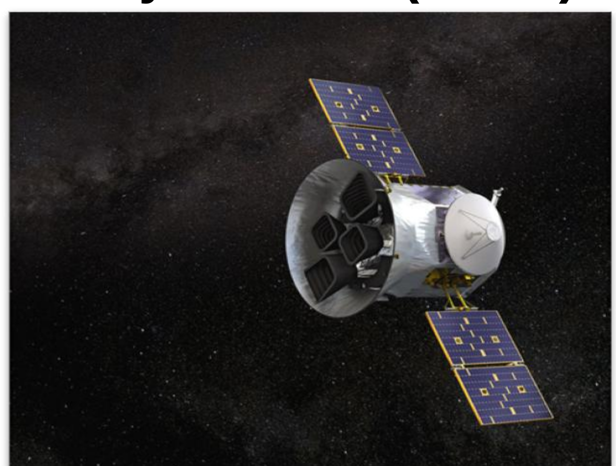
The All Sky Automated Survey

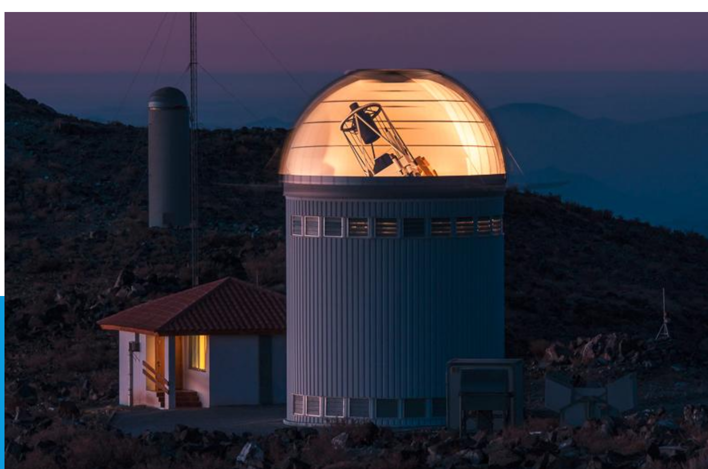
PLATO-A at Dome A with AST3



The Transiting Exoplanet Survey Satellite (TESS)



OGLE



The HATNet Exoplanet Survey

ASAS (All Sky Automated Survey)

-The catalog of variable stars II, 6h – 12h Quarter of Southern hemisphere (Pojamski, 2004)
- ASAS – 3 prototype located at Las Campanas Observatory
- discovered 11,357 variables V<14 mag, south of +28º declination
- 2685 eclipsing binaries – 1317 contact binaries (2 objects)
- positional accuracy < 3”, differential mag. Accuracy ~ 0.01 mag

OGLE (Optical Gravitational Lensing Experiment)

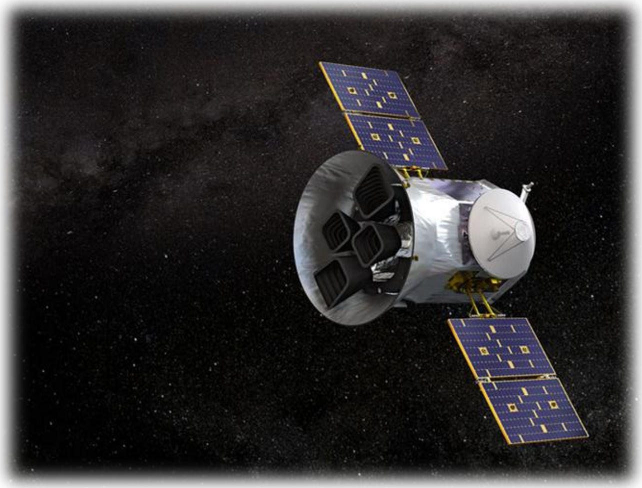
- OGLE IV catalog (since 2010) observed 400 million stars in galactic bulge (Soszynski et al., 2016)
- 1.3 m Warsaw telescope at Las Campanas Observatory
- faintest star ~ 21 mag, accuracy 0.005 mag
- 4,25,193 eclipsing binaries (48 objects)

The HATNet (Hungarian Automated Telescope Network) Survey

- Galactic plane, field chosen to overlap NASA's Kepler mission (Hartman et al., 2004)
- HAT5 telescope at Fred Lawrence Whipple Observatory
- 98,000 bright sources, 1617 variables with 89% new discoveries (3 objects)
- bright sources observed with I< 14.8 mag, accuracy ~ 0.06 mag

AST3 – Dome A (Antarctica Survey Telescope)

-Chinese small telescope array CSTAR at Dome A of Antarctica (Yuan et al., 2008)
- prototypes AST3-1, 2 telescopes (Wang et al., 2017)
- 96,734 bright stars, 285 binary stars,143 new discoveries (6 objects)
- bright sources mag 10.8 – 16.2



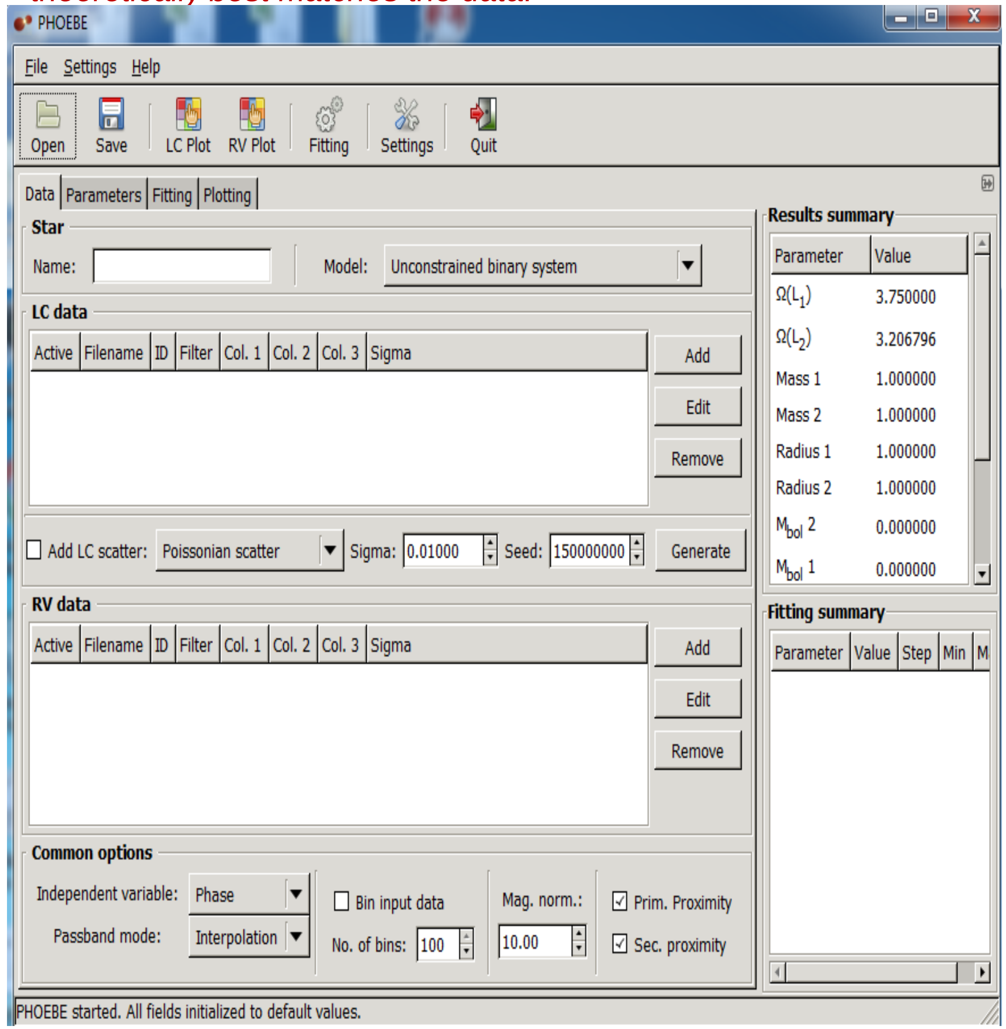
The Transiting Exoplanet Survey Satellite (TESS)

- two-year survey of extrasolar planets in both celestial hemispheres, 30 observation sectors of (24º x 96º) strips of the sky (extended till 2022)
- four identical, highly optimized, red-sensitive, wide-field cameras (Ricker et al., 2015)
- 2 min & 30 min cadence data
- thousands of transiting exoplanets and false positive eclipsing binaries (2 objects)

- Partially eclipsing contact binaries – q poorly estimated through photometry (Pribulla et al., 2003 and Terrell & Wilson, 2005)
- Speculations on reliable values of q through spectroscopy (due to broadening and blending (Dall et al.,2005 and Rucinski, 2010)
- Totally eclipsing contact binaries photometric q correspond their spectroscopic values (Pribulla et al., 2003)

Mission	ASAS	OGLE	HATNet	AST3	TESS
No. of objects	2	48	3	6	2
towards	disk	bulge	disk	disk	disk
Periods (d)	0.3787-0.7419	0.3486-0.9598	0.4258-0.9731	0.3672-0.7808	0.50449-0.53480
Distance (pc)	227.8-321.1	659.2-3003.9	891.4-11299.4	1536.8-4280.8	738.2-1196.5
$T_{effective}$ (K)	6475-5475	4092-6512	5574-6541	4897-5873	6450-5959

PHOEBE is modeling package built on the Wilson-Devinney code to run on experimental light curves and radial velocity curves. PHOEBE estimates physical parameters of an eclipsing binary that theoretically best matches the data.



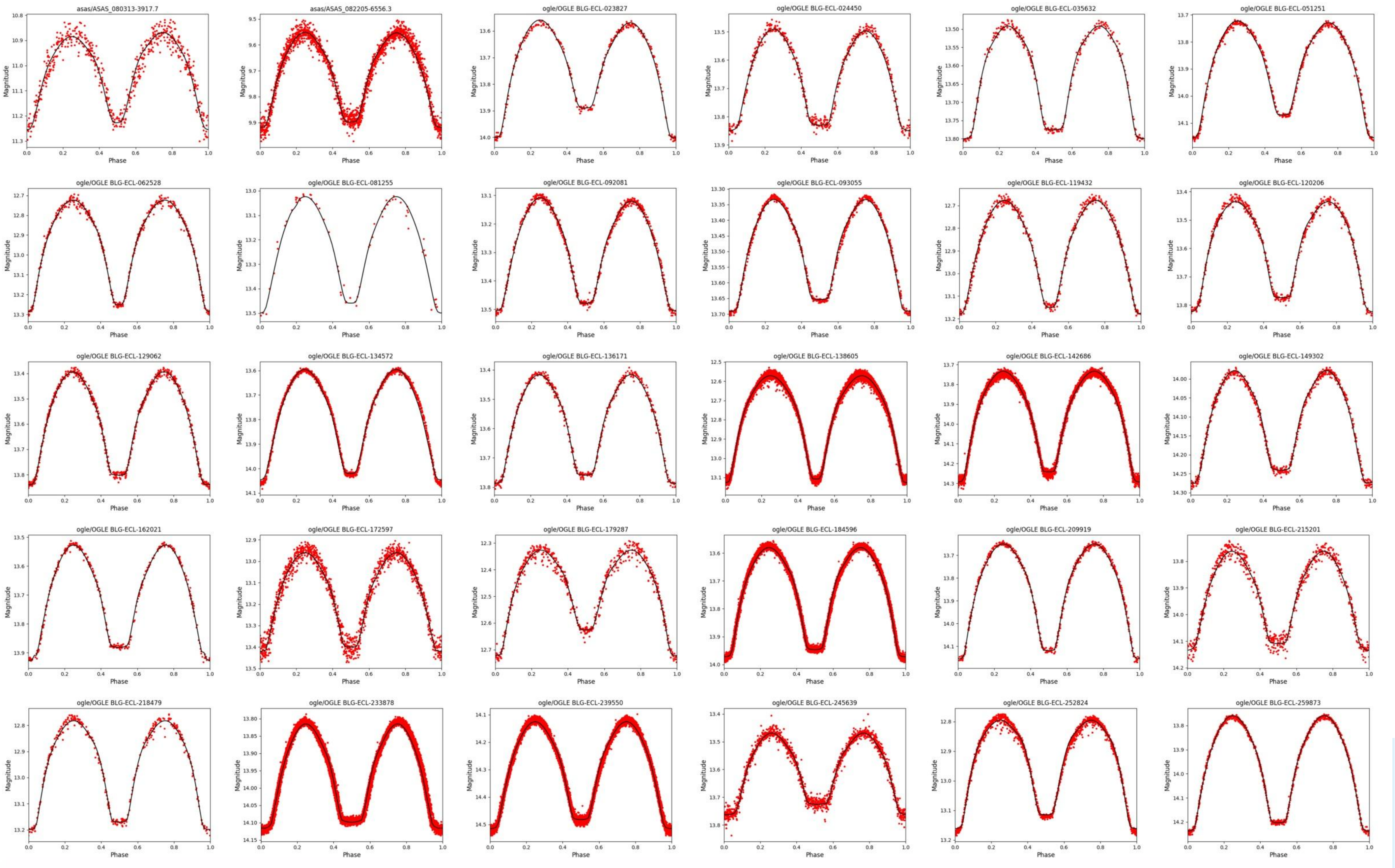
Light curve analysis method

- Epoch-Persea (Schwarzenberg-Czerny, 1996)
- Phase folded light curves obtained
- Light curve analysis run using PHOEBE v 0.31a (Prsa, 2006)
- Initial parameters were taken following standard procedures
- Effective temperatures from GAIA (Gaia Collaboration, 2018)
- After a q search, q, T_2, L_1, i and Ω were taken as adjustable parameters and iterations performed to get synthetic light curves with minimum $\Sigma(O\text{-}C)^2$ between observations and synthetic light curves

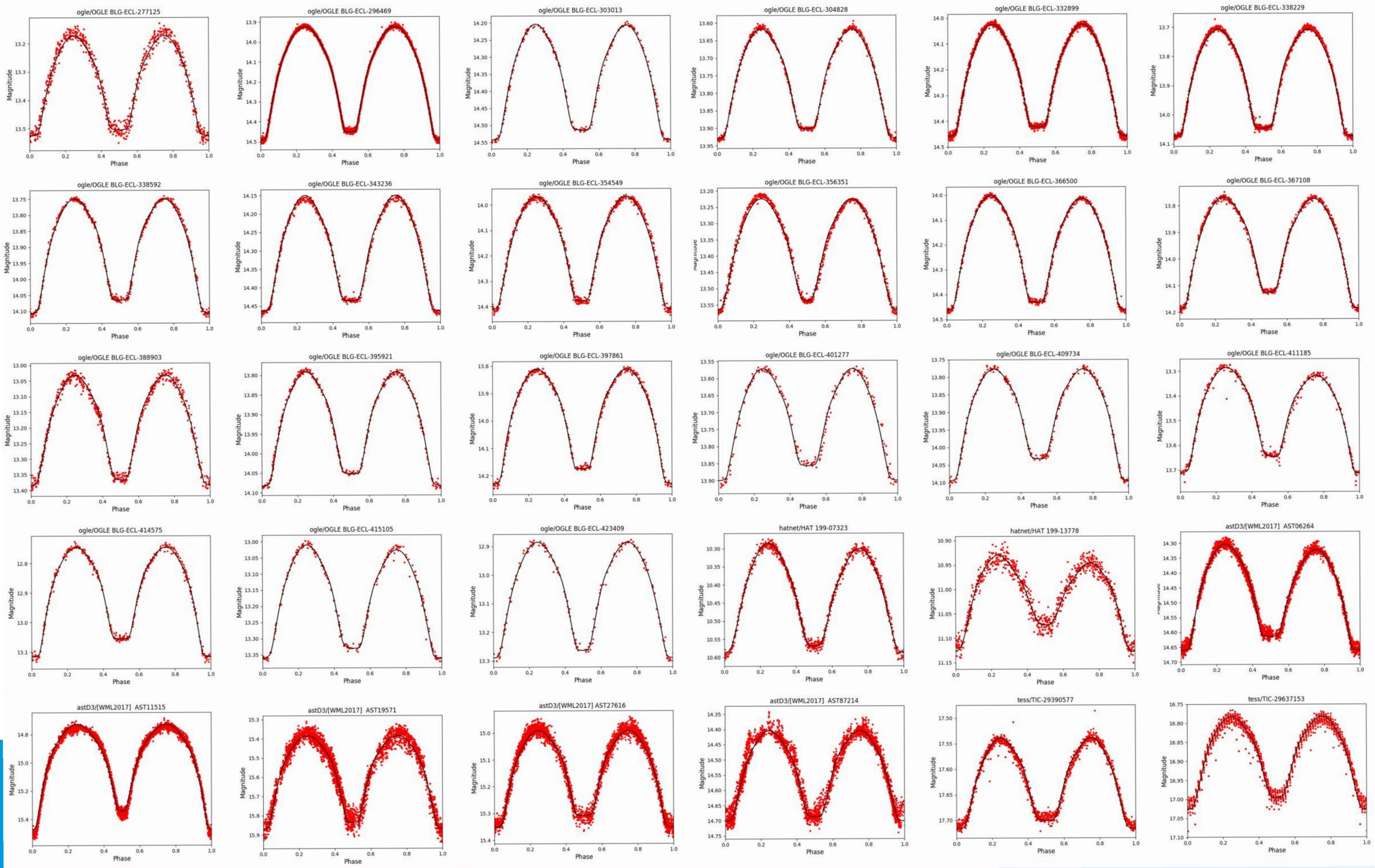
Mission	ASAS	OGLE	HATNet	AST3	TESS	Total
Mass Ratio	0.197-0.220	0.132-0.380	0.096-0.180	0.143-0.504	0.076-0.129	0.076-0.504
ΔT (K)	268-316	48-812	282-1009	220-410	415-508	48-1009
Fill out factor (F) %	11-35	3-85	21-49	18-31	3-26	3-85
Primary Mass ($M_\odot$)	1.29-2.11	1.16-2.52	1.42-2.65	1.18-2.20	1.71-1.72	1.16-2.65
Secondary Mass ($M_\odot$)	0.28-0.42	0.21-0.64	0.14-0.36	0.26-0.59	0.13-0.22	0.13-0.64

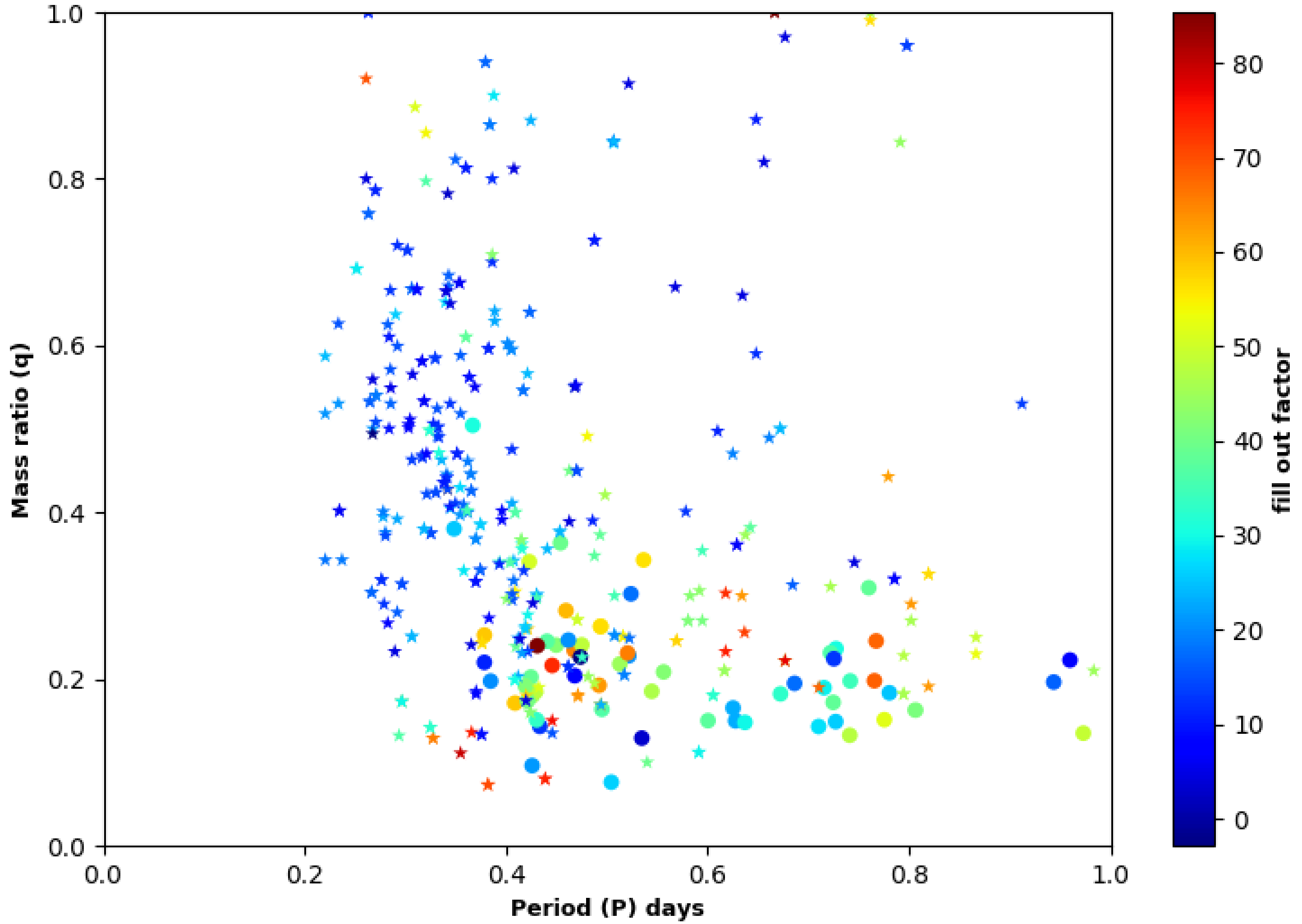
The selected binaries fall in a range of short period, low mass ratio, F5-M0 spectral types and wide range of fill out factors.

Observations . Theoretical fit -



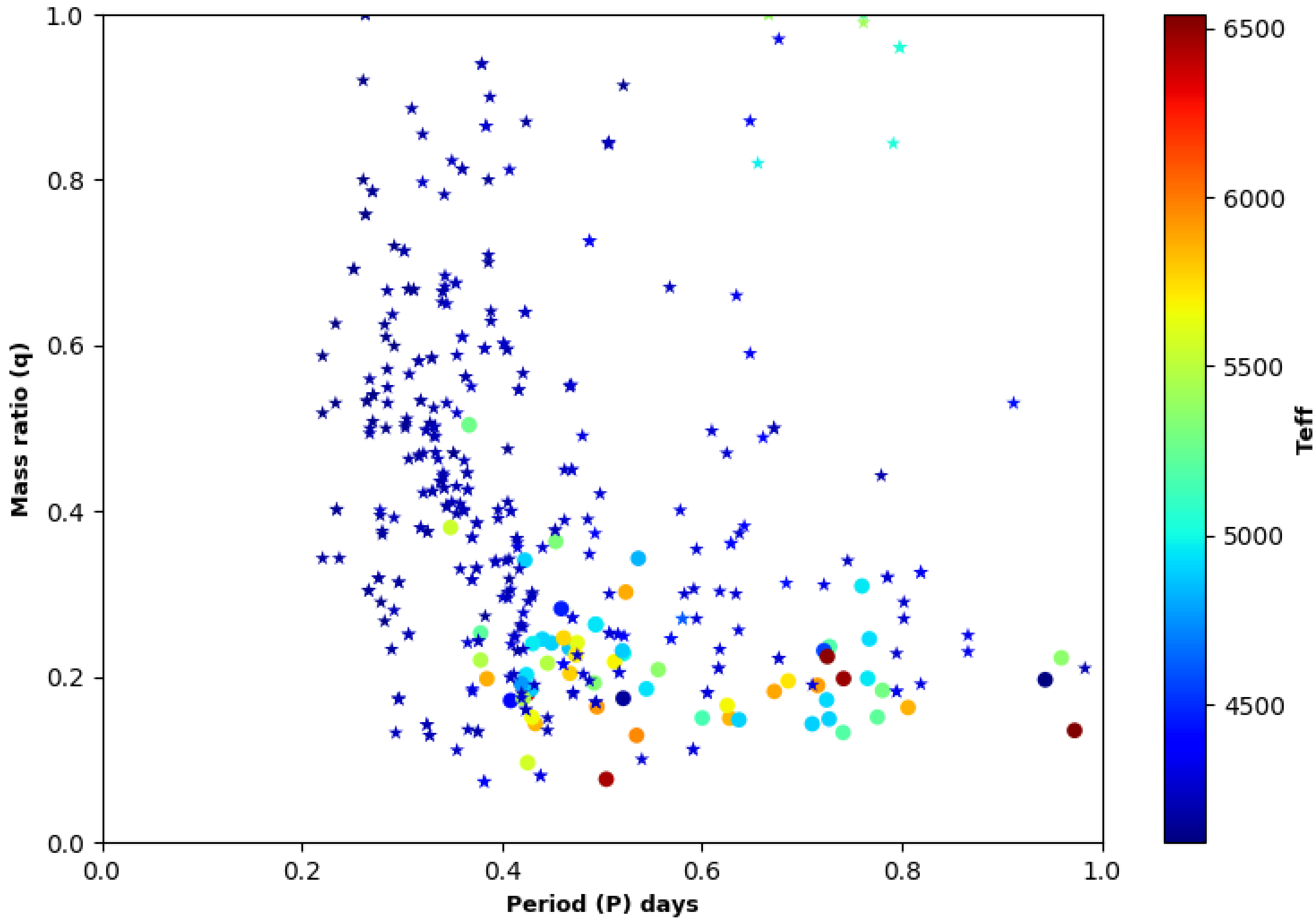
Observations . Theoretical fit -





Reference catalogs: Pribulla et al., 2003; Csizmadia, 2004; Deb & Singh, 2011

5 Marginal contact binaries (F<10%)
15 Deep contact binaries (F>50%)
41Over contact binaries (10% ≤ F ≤ 50%)



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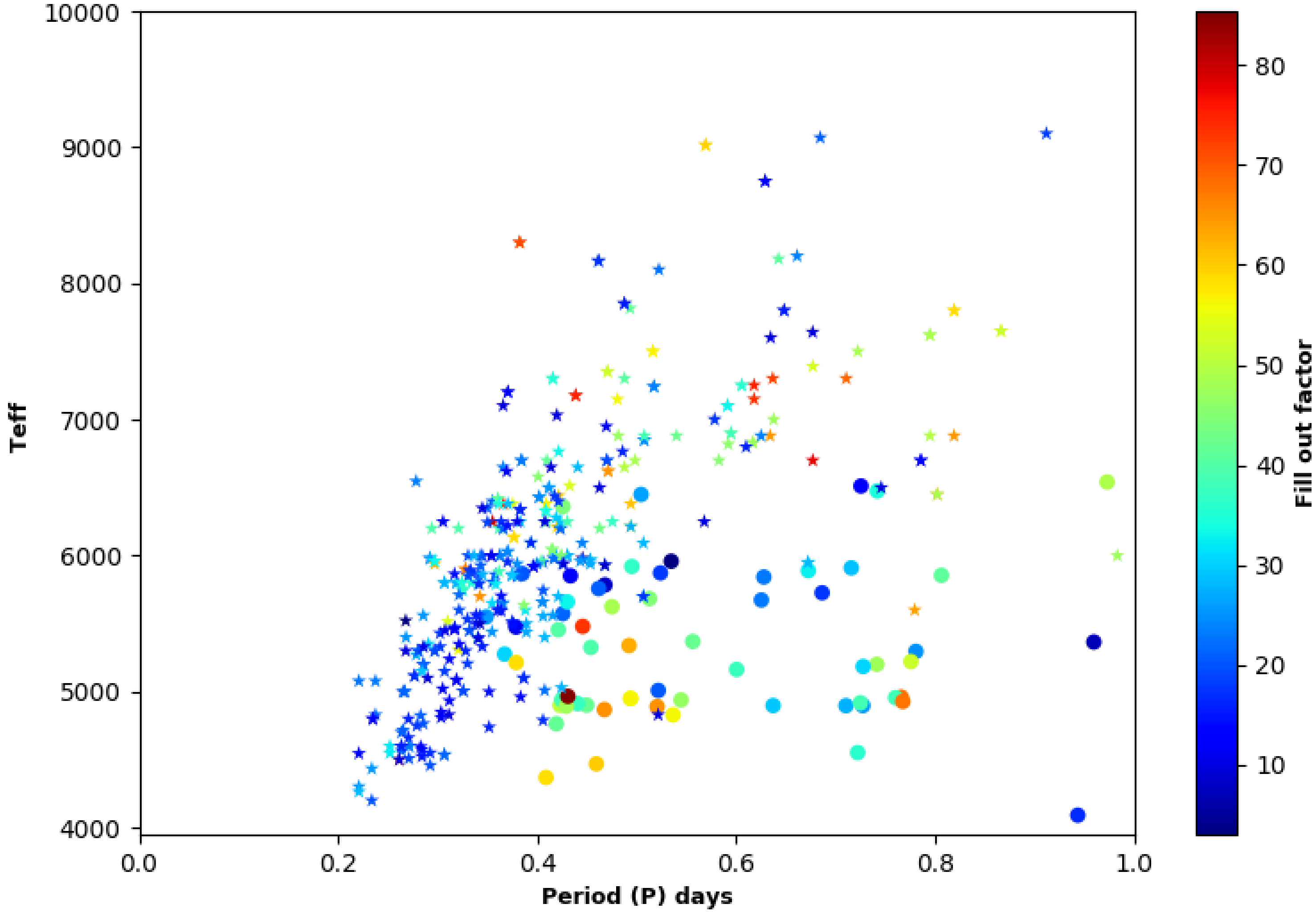

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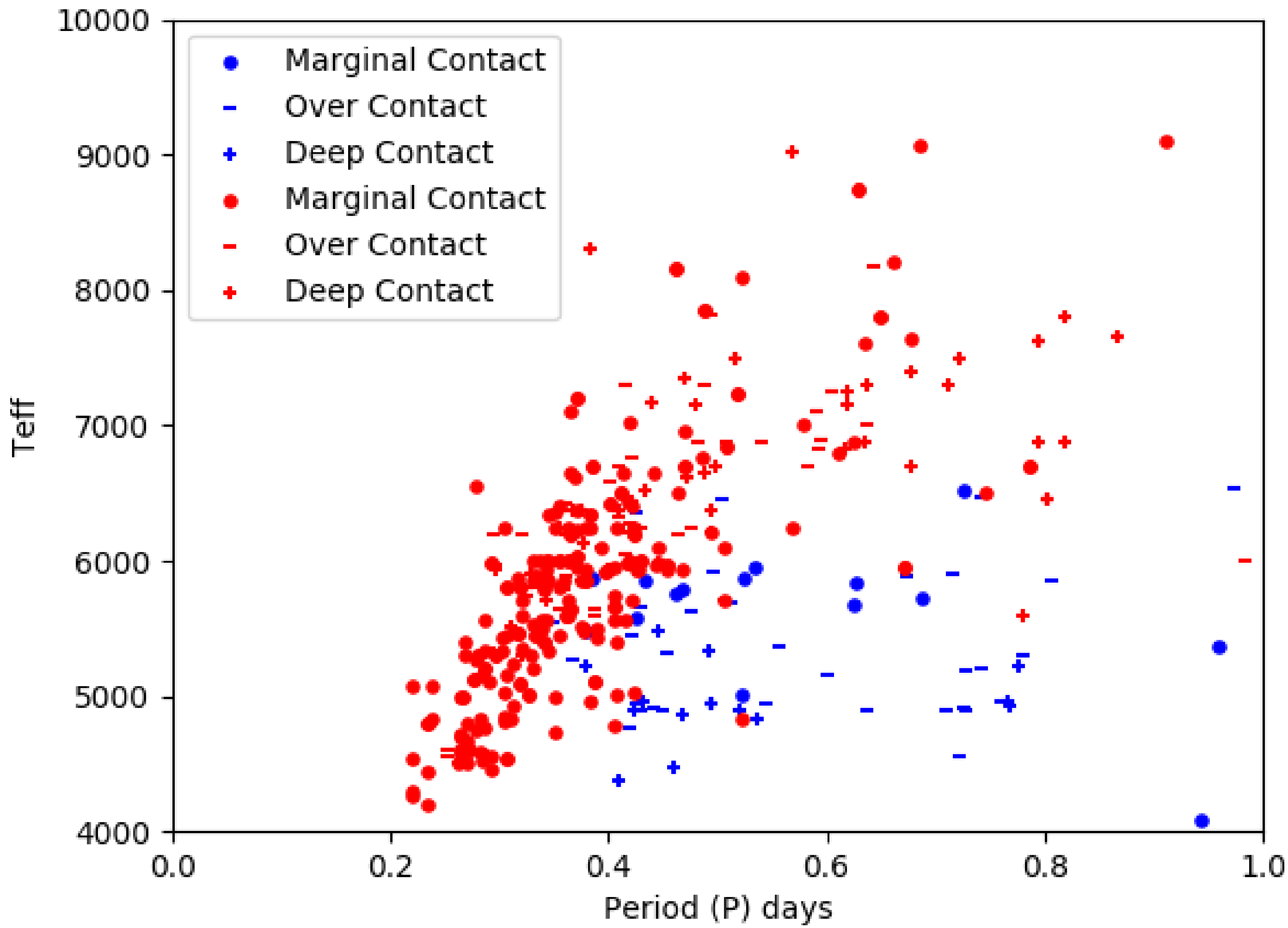
All binaries in SPBE region represent average sample of contact types of eclipsing binaries with a short period (Molik & Wolf, 2003)



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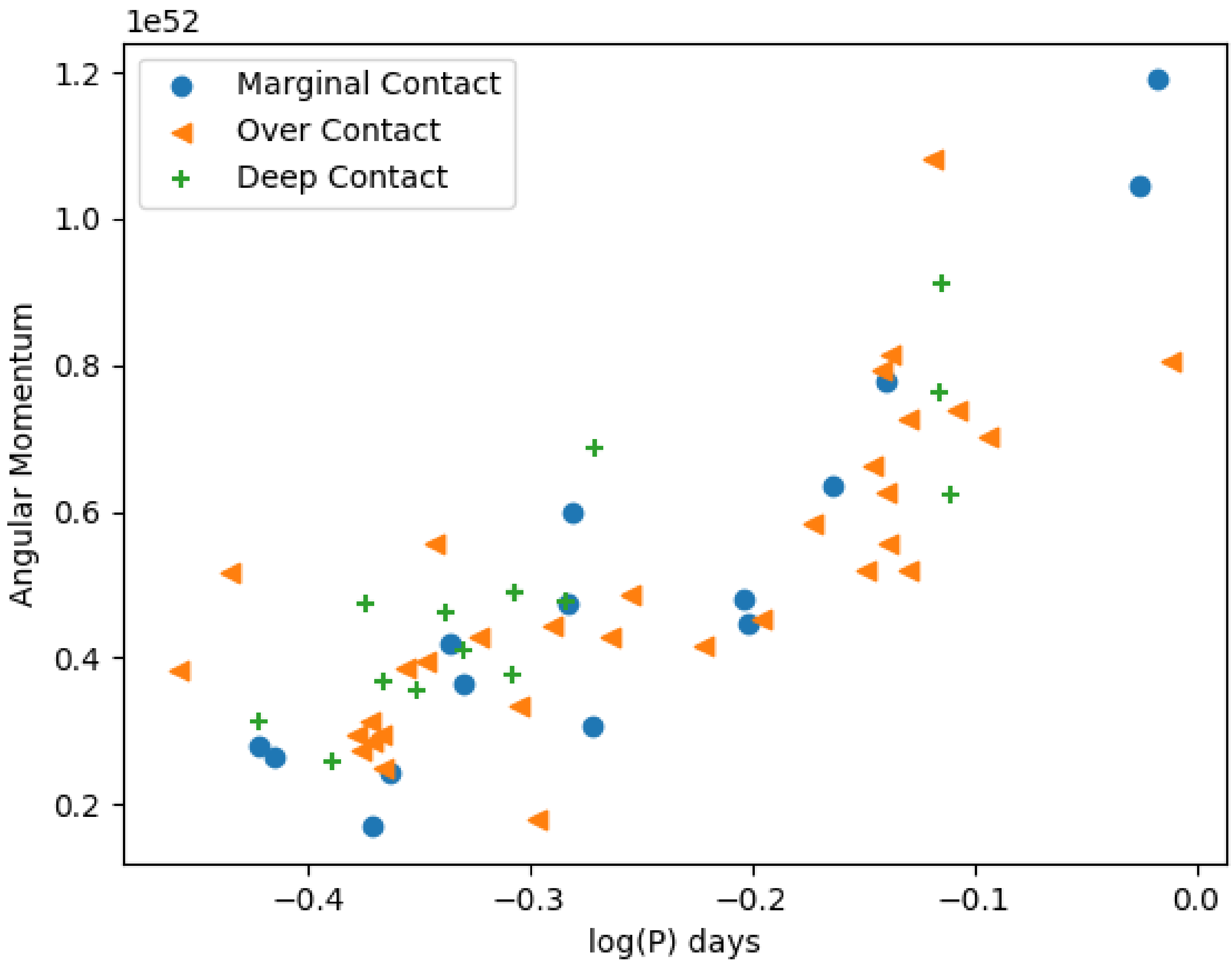
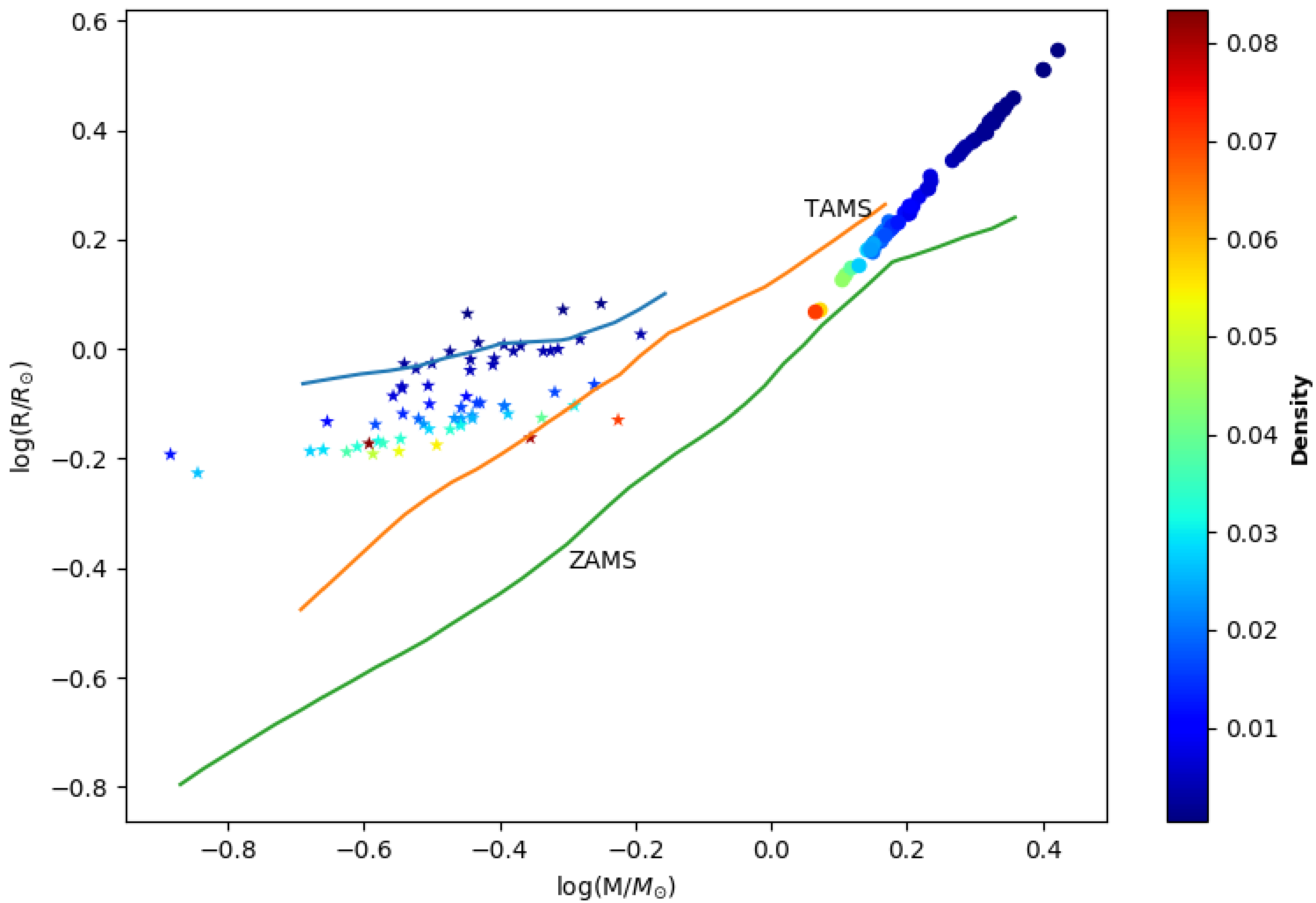
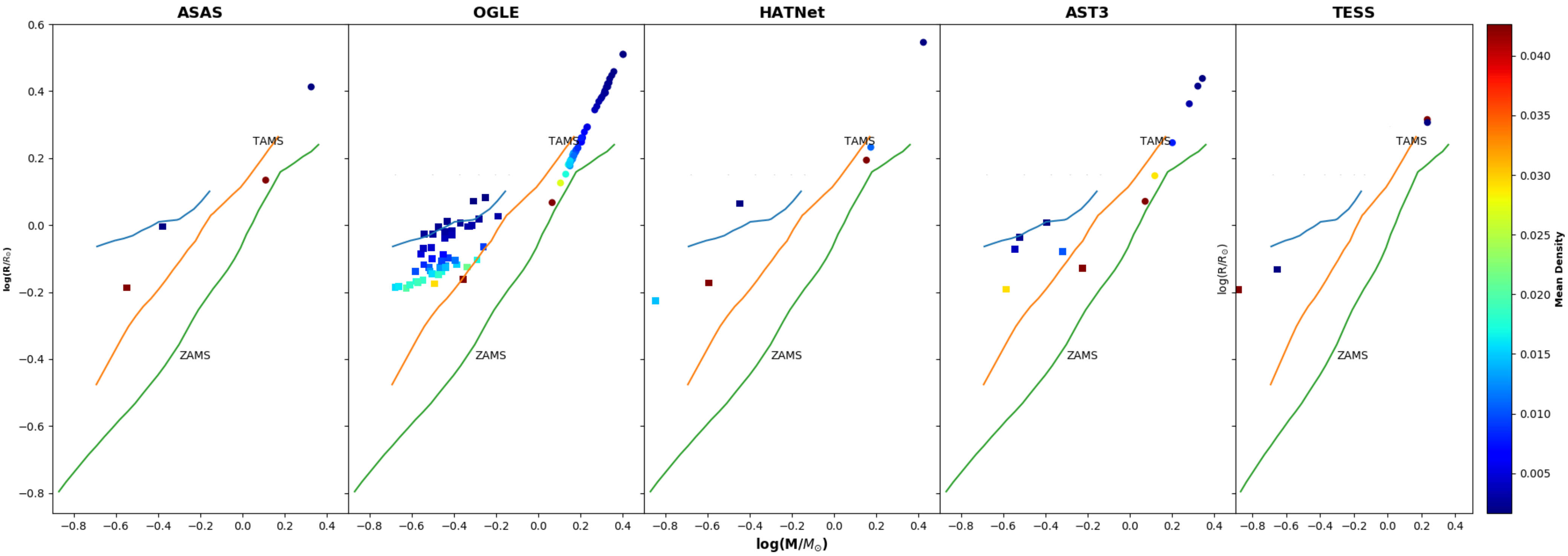


Angular Momentum $H_{orbital}$ (in CGS units) (Stepien & Gazeas, 2012) ; $H_{\odot}$ = 1.63 x 10^{48} CGS units
A decrease in H with period.



ZAMS (lower) and TAMS (upper) lines for solar-metallicity are obtained from Girardi et al. (2000); Stepien, 2004.


ASAS
OGLE
HATNet
AST3
TESS
TAMS
ZAMS
log(R/$R_\odot$)
log(M/$M_\odot$)
Mean Density
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005

Conclusions:

- All the objects in study are short period late type binaries between spectral range F5-M0
- As all the binaries in study are totally eclipsing, the mass ratio's and the photometric elements determined are more reliable.
- The absolute parameters were derived for the (**Gazeas, 2009)** relations
- It is observed that most of the binaries in study are low mass ratio systems with massive primaries and few systems are found to have very low mass ratios and such systems are observed to be interesting sources for followup observations to understand the evolutionary models.
- Very few systems (V410 Aur, XY Boo, V857 Her, AH Cnc, V1191 Cyg, V728 Her, V441 Lac) have been studied in literature which showed this less mass ratio in period range between 0.30-0.47days.
- Out of 61 objects 15 are in Marginal, 31 are in over contact and 15 are in deep contact configuration.
- The objects in the direction of bulge region mostly were observed to show over contact phase

- High temperature differences between the components were observed in few systems which could be due to transition between contact and broken contact phase of thermal relaxation oscillation (TRO) model, which is evident from low fill out factors

- From log M vs log R and p vs Teff plots we observe that most of the binaries in the sample are evolved systems with overluminous secondaries.

- The results add-on to the existing evidence that in short period contact binaries, late-type systems are more in frequency compared to early type contact systems based on evolutionary history of contact binaries. (giuricin et al 1983)

- The co-relation studies(diagrams) and calibrating the empirical relations across the entire range of parameters will act as strong tool for calculating the physical parameters of contact binary stars.

- Studying more number of objects in the short period cut-off range will allow the correlations to be tested further and improve upon the results in the development of better evolutionary models.

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THANK YOU