What we can learn from Eclipsing Binaries in Large Surveys: The case of EA Catalina systems

Athanasios Papageorgiou[1,2], Márcio Catelan[1,2,3,6], Panagiota-Eleftheria Christopoulou[4], Andrew J. Drake[5], and S. G. Djorgovski[5]

[1] Pontificia Universidad Católica de Chile, Facultad de Física, Instituto de Astrofísica, Av. Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chil
apapageo@astro.puc.cl
[2] Millennium Institute of Astrophysics, Santiago, Chile
[3] Centro de Astro-Ingeniería, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile
[4] Department of Physics, University of Patras, 26500, Patra, Greece
[5] California Institute of Technology, 1200 East California Boulevard, Pasadena, CA 91225, USA

EB systems are important!

by-product of several wide-field, ground-based photometric surveys

- the Optical Gravitational Lensing Experiment (OGLE, Udalski et al. 1992) survey
- the All Sky Automated Survey (ASAS, Pojmanski 1997; Pojmanski et al. 2005),
- the asteroid survey LINEAR (Stokes et al. 2000; Palaversa et al. 2013),
- the Catalina Sky Survey (CSS, Larson et al. 2003),
- the Northern Sky Variability Survey (NSVS, Woźniak et al. 2004),
- the Transatlantic Exoplanet Survey (TrES, Alonso et al. 2004, 2007),
- the Hungarian-made Automated Telescope Network exoplanet survey (HATNet, Bakos et al. 2004),
- the Wide Angle Search for Planets (SuperWASP, Christian et al. 2006; Pollacco et al. 2006), (see Kovacs 2017; Soszyński 2017, for recent reviews and references).
- the Visible and Infrared Survey Telescope for Astronomy (VISTA) Variables in the Via Lactea (VVV, Minniti et al. 2010; Catelan et al. 2013),
- CoRoT (Convection, Rotation & planetary Transits, Baglin et al. 2007)
- KEPLER (Prša et al 2011a, Borucki et al. 2010)
- GAIA (Eyer et al. 2017; Gaia Collaboration et al. 2018b) and

- the future LSST (LSST Science Collaboration et al. 2009)

- In addition …. large spectroscopic LAMOST (Qian et al 2018)

EA-type eclipsing systems on the basis of light-curve (LC) morphology, with clearly defined eclipses on their LCs,

include both **(D) detached and semi-detached (SD) systems**. As a rule, in order to establish the actual system configuration of any individual EB with such an Algol-type LC morphology,

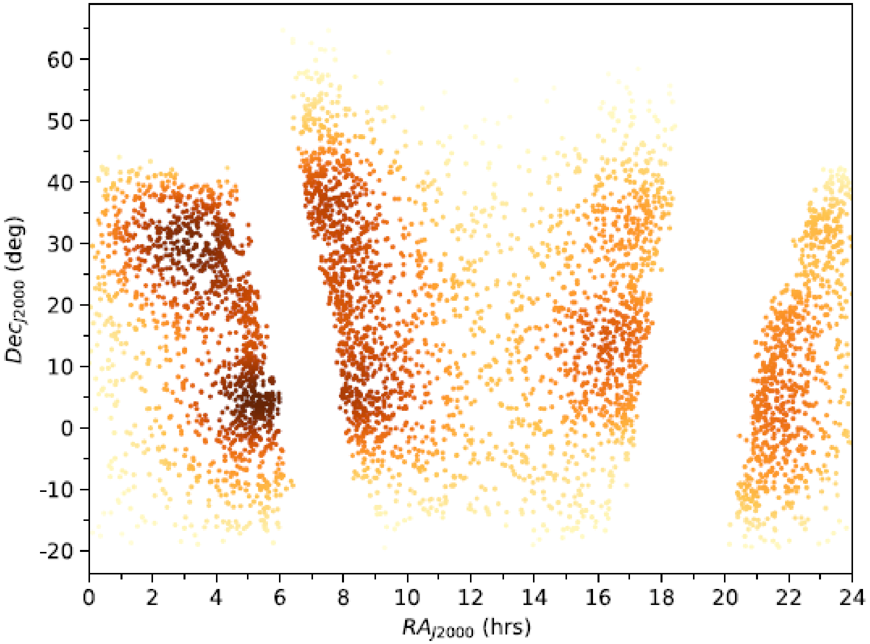
A **detailed physical modeling is required**.

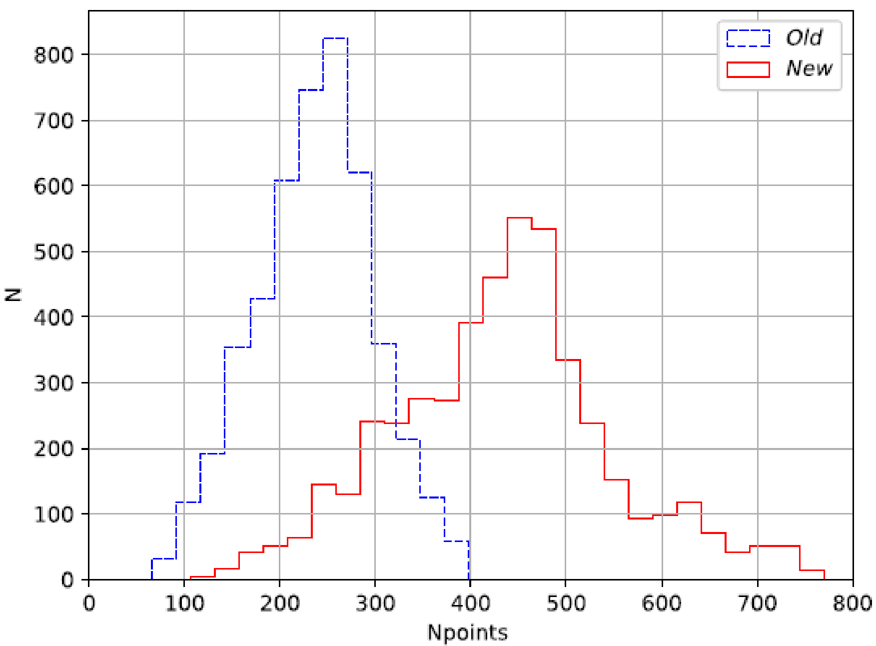
- EA –type good chance to investigate several astrophysical processes (interaction, mass transfer, magnetic braking)
- Evolutionary connection EAs-EWs ?
- EAs can contain low-mass stars

How many EAs in the catalogues;

2874 in the GCVS (Samus et al. 2017) (from many different sources),
23307 in the International Variable Star Index (VSX) by American Association of Variable Star Observers (AAVSO) (Watson et al. 2006)),
2956 in the LAMOST survey (Qian et al. 2018),
357 in the LINEAR survey (Palaversa et al. 2013) and
4683 in the Catalina Sky Survey (Drake et al. 2014)

CSS Observations





The Catalina Sky Survey[1] (CSS) observations used, 3 telescopes 2004-2016, in order to discover near-Earth objects (NEOs) and potential hazardous asteroids (PHAs).
Each of the survey telescopes is run as a separate subsurveys.

The Catalina Real Time Survey (CRTS) cataloged about 47000 periodic variable stars in Data Release-1 (Drake et al. 2014). Focus on **4683 EA (Drake et al. 2014b, 8 years) of** Catalina Surveys Data Release 2[2]
CSDR2+ (2004-2016) 12 years
Aperture photometry (SExtractor, Bertin & Arnouts 1996).), unfiltered and transformed to V_{CSS}~V
RA =[0^h -24^h] δ=[−22°, +65°]

[1] http://www.lpl.arizona.edu/css/
[2] http://catalinadata.org

Papageorgiou et al. 2018 ApJS..238....4P, 2019ApJS..242....6P, ***to be submitted***

present an updated a more detailed catalog of EA

- revise periods and class
- derive the phenomenological and physical parameters
- search for systems exhibiting long-term variation, that potentially harbor low-mass components
- Search for low-mass EBs
- Search for period variations

Goals of this study /every survey.

- to provide a set of EA parameters that allows to study the ensemble of EAs on a statistical ground without the need to model the binary system.
- to identify within the large data set binary systems with unexpected properties that could reveal the existence of new configurations.

Papageorgiou et al. [2018 ApJS..238....4P]

Cleaning of the 4683 LCs of the initial sample

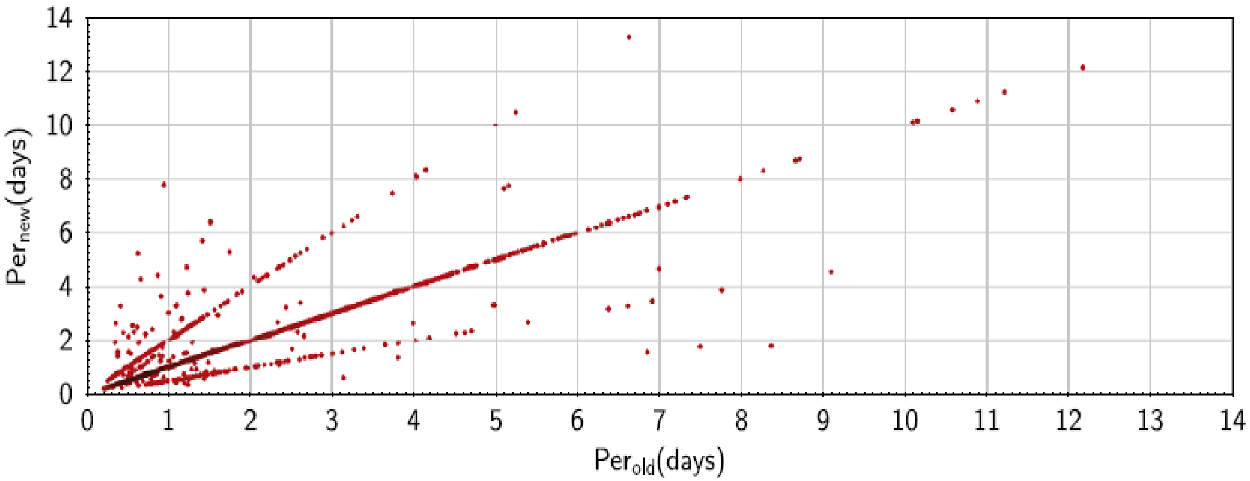
a sigma-clipping cutoff algorithm was used to discard erroneous data points with values outside the interval of ±5σ of the median relative flux

by adopting a pre-defined period from Drake et al. (2014b), we performed 5σ clipping from the median value of each phase bin.

Period Search

- Analysis of Variance (AoV, Schwarzenberg-Czerny 1989,and Devor 2005);
- Box-Least Squares (BLS, Kovács et al. 2002);
- Generalized Lomb–Scargle (GLS, Press et al. 1992;Zechmeister & Kürster 2009);
- Phase Dispersion Minimization (PDM, Stellingwerf 1978); and
- Correntropy Kernelized Periodogram (CKP, Protopapas et al. 2015).

Common issue encountered using periodograms, **double/half period detection**. the majority of the phasefolded LCs were also examined using twice/half the detected period



Refined P. improved values are now available for ~10% of the stars

LC Phenomenological-morphological features Parameters

LC fitted LMFIT

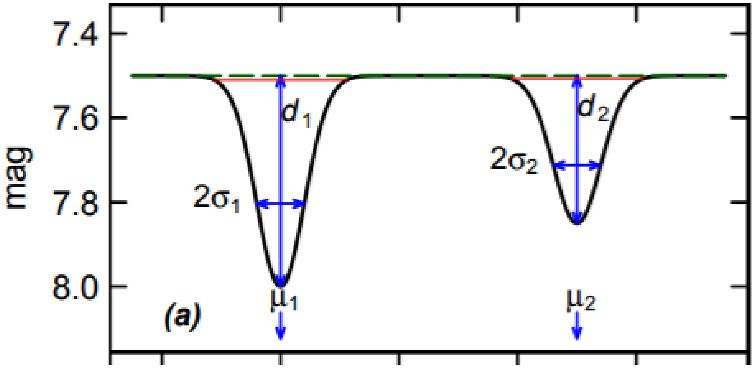
(Newville et al. 2016) module in Python

a chain of second-order polynomials (Prša et al. 2008; Papageorgiou et al. 2014)

Fourier series fitting

a two-Gaussian model (**TGM**, Mowlavi et al. 2017).

LM parameter values as starting points
phases (μi),
half widths (σi),
depths (di) of the primary and secondary eclipses (i=1, 2),
peak-to-peak amplitude of the ellipsoidallike variation(Aell)
and a constant (C) that equals the maximum light of the LC
in the case of detached systems (Mowlavi et al. 2017)



The actual fitting process was overseen by the Levenberg–Marquardt nonlinear minimization algorithm.

a Markov Chain Monte Carlo (MCMC) analysis was performed on each TGM

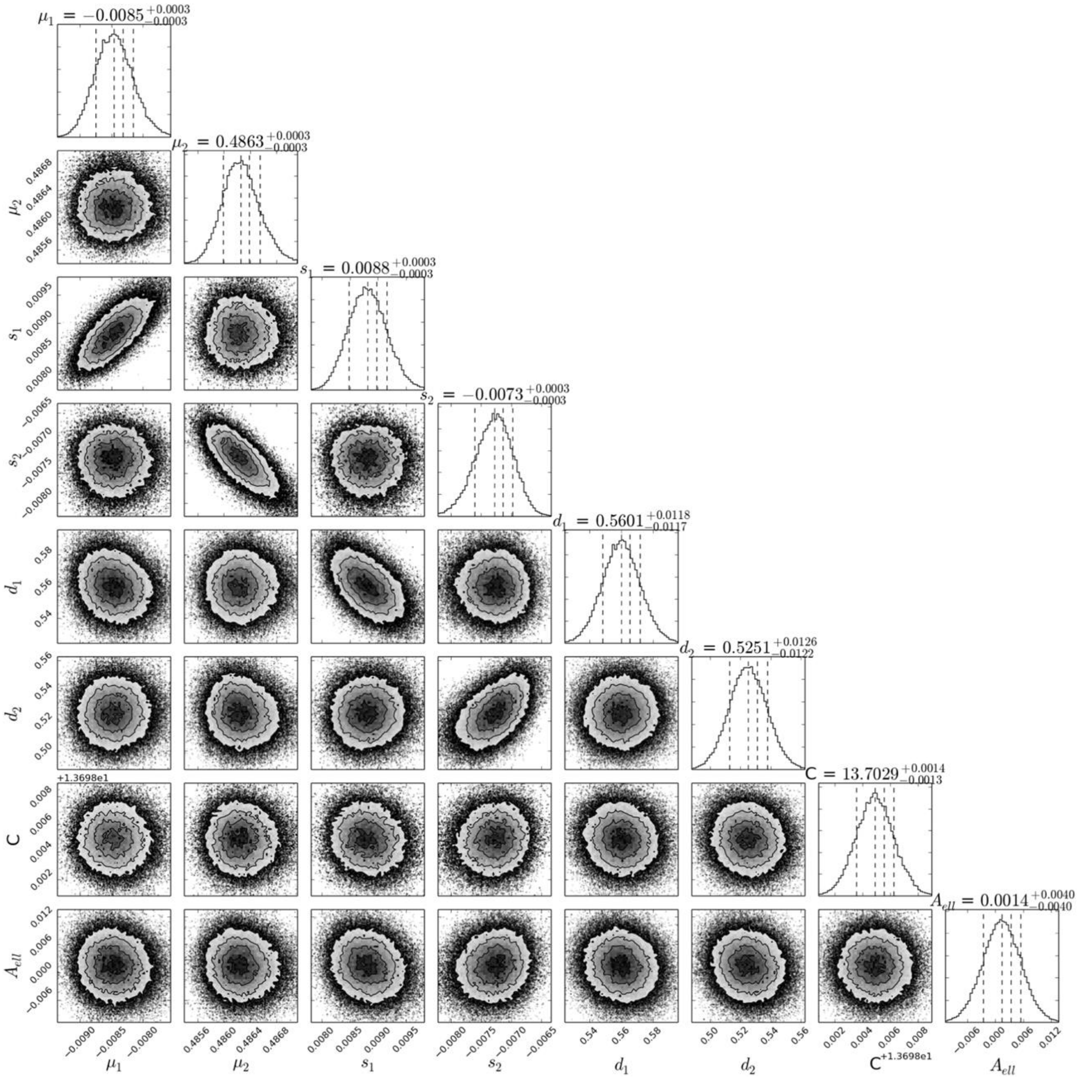
Normal distribution based on the final LM parameter values +errors

Initial guesses MCMC

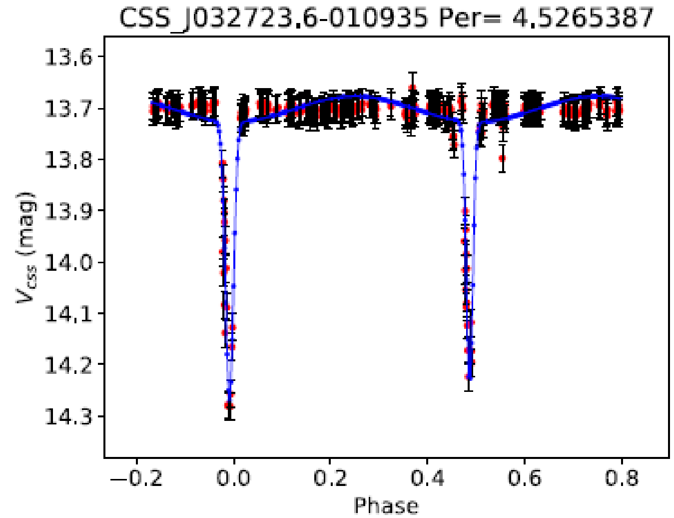
New Fit rejected or accepted based on Metropolis–Hastings algorithm (Hastings 1970)

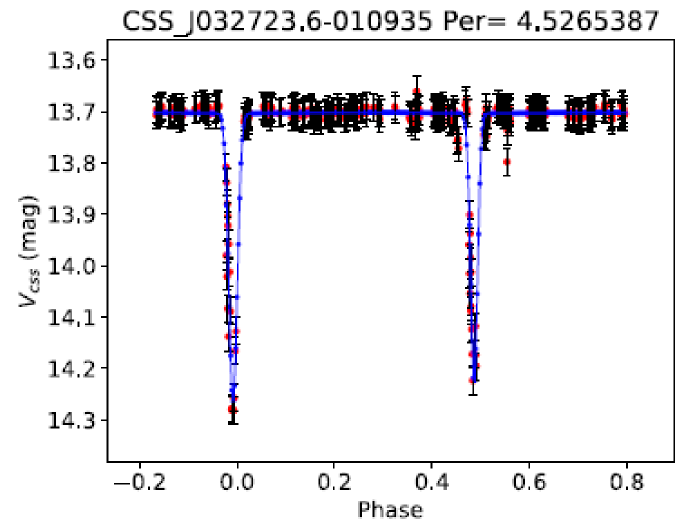
Discard the first 15000 steps

sampled the New synthetic model



one-dimensional and two-dimensional projections of the posterior probability distributions (Foreman-Mackey et al. 2014) of a few parameters inferred from the TGM on each light curve.

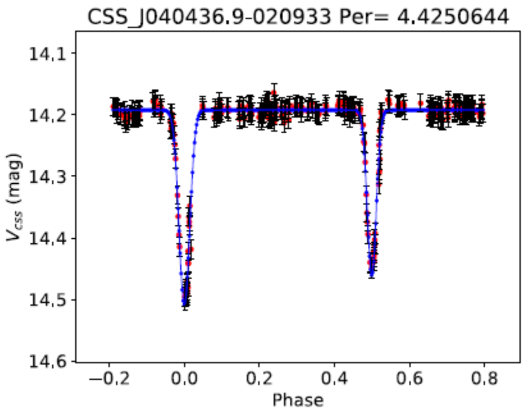


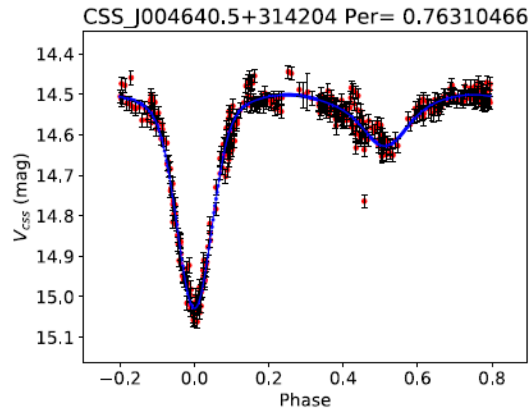


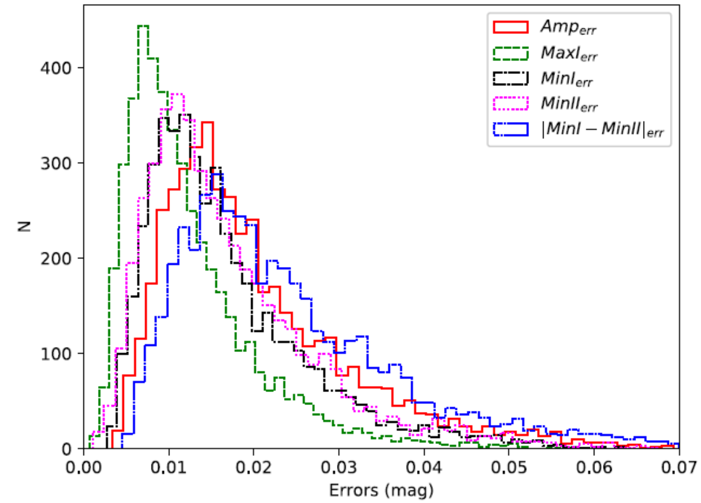
LC with the initial (top) and the final (bottom) TGM fitting coupled by MCMC

Phenomenological Parameters of 4680 EBs

Name	Amp (mag)	Amp_{err}[a] (mag)	MinI (mag)	$MinI_{err}$[a] (mag)	MinII (mag)	$MinII_{err}$[a] (mag)	MaxI (mag)	$MaxI_{err}$[a] (mag)	|MinI–MinII| (mag)	$\|MinI–MinII\|_{err}$[a] (mag)
CSS_J235945.5+303731	1.9357	0.0225	15.6800	0.0205	13.8708	0.0130	13.7176	0.0145	1.8092	0.0216
CSS_J235856.7+371823	0.2647	0.0083	13.5267	0.0061	13.3597	0.0069	13.2358	0.0062	0.1669	0.0088
CSS_J235816.7+293325	1.4841	0.0276	18.2052	0.0231	16.9536	0.0242	16.6789	0.0180	1.2516	0.0321
CSS_J235756.9–023247	0.6316	0.0344	13.3882	0.0269	13.2883	0.0288	12.7309	0.0239	0.0999	0.0379
CSS_J235715.5+305455	0.3071	0.0087	14.6847	0.0082	14.6709	0.0076	14.3497	0.0031	0.0137	0.0111
CSS_J235538.3+384723	0.2798	0.0150	16.6196	0.0117	16.4139	0.0152	16.3397	0.0104	0.2057	0.0192
CSS_J235444.8+305751	0.8093	0.0271	16.7195	0.0188	16.5878	0.0268	15.8768	0.0214	0.1317	0.0316





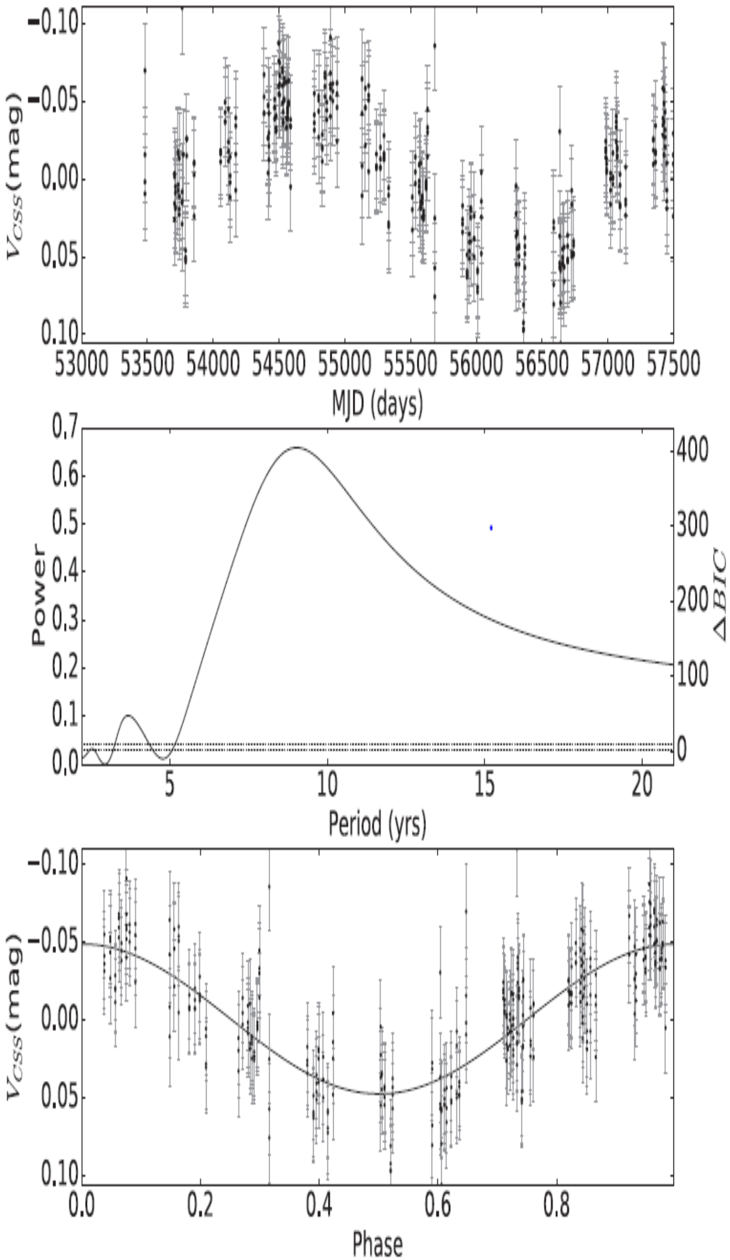


Classification

- visual inspection?
- Lee (2015) MECI (Method for Eclipsing Component Identification, Devor & Charbonneau 2006), based on Roche lobe filling criteria found 272 SD EBs among 2170 fitted LCs (of the total 4683)
- for the first time automated classification of the majority of EA-type CSS (unsupervised machine-learning followed, by supervised learning) EBs with machine-learning algorithms….

The final catalog, contains 3456 D (85%), 449 SD (11%), and 145 EBs (4%) with uncertain classification (D/SD).

Different maxima in 12 year time span…. In order to detect significant variations over long (~5–10 years)

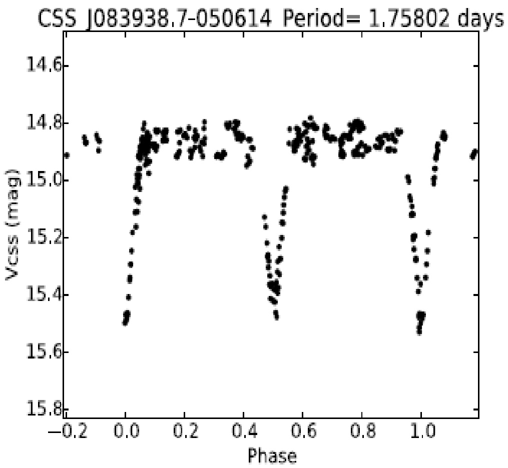


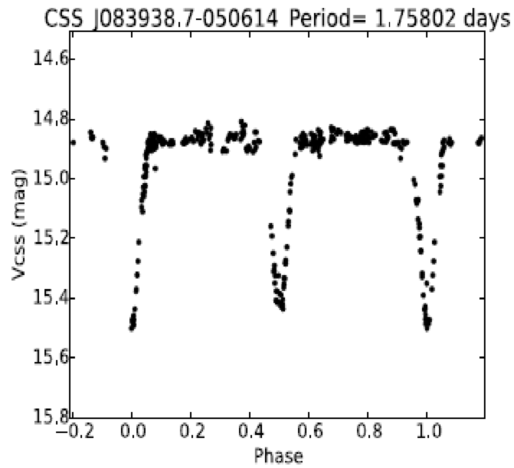
subtract the TGM phenomenological model from the time-series observations

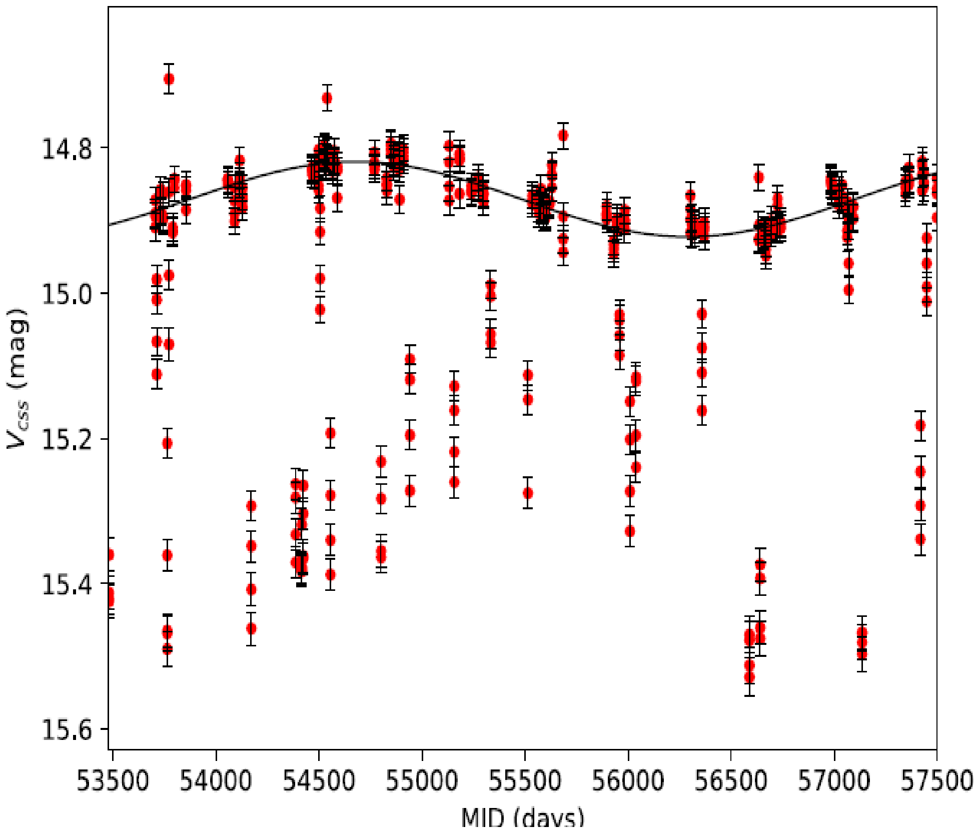
perform a Generalized Lomb–Scargle

GLS analysis of the residualS

evaluate the possible presence of periodicity in this variation







- Bin the LCs in time
- Calculate the median value and std for each such bin
- Remove the eclipses by selecting the data points in the neighborhood of the median values, applying 1σ tolerance
- calculate through a GLS periodogram the amplitude and the period of binned LCs

or

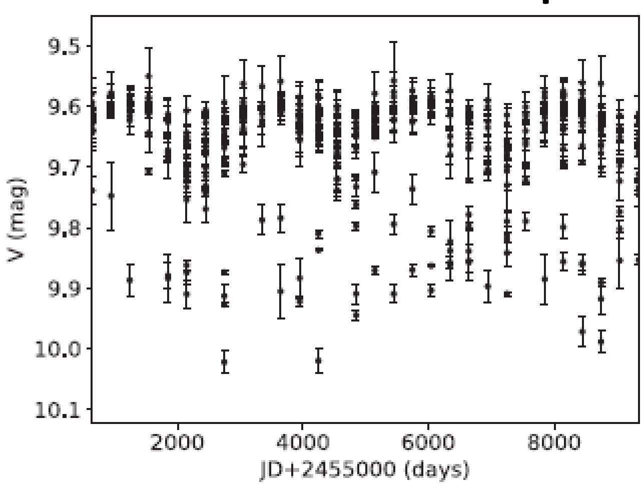
- By applying a harmonic fit to the time binned data
- Examine for contamination SDSS sources <5”

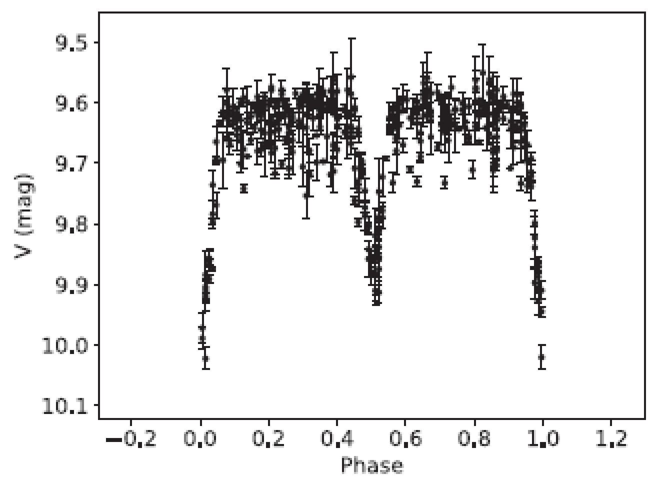
2.5 % of the sample (119 EBs in the sample of 4680 EBs) with cyclic or quasi-cyclic maximum light variation. ΔL/L [0.04–0.13], with a mean value $(\Delta L/L) = 0.075 \pm 0.017$, P[4.5–18] years, with a mean P=12.1 ± 3.3 years

What mechanism can cause maximum light variations in EBs?

Applegate mechanism (Applegate 1992)
Fractional luminosity variations of $\Delta L/L \sim 0.1$ of the active(s) star(s) can produce period variations of $\Delta P/P \sim 10^{-5}$.
The majority of the 119 EBs match with 2MASS (Skrutskie et al. 2006) sources with colors J−H>0.237 mag and H−K>0.063 mag, which implies Teff<~6200K (Pecaut & Mamajek 2013).

Cool starspot coverage due to the magnetic activity …
Simulate spotted EB with a magnetic cycle of 6.3 years observed (1/300 days) for a total time-span of 9000 days +variable random noise (PHOEBE-2.0 engine (Prša et al. 2016)
Variabe size of cool starspot regions





Large starspot regions
or
both stars must show magnetic activity

What is needed?
Accurate times of minimum light observations and period variation analysis

L o w m a s s EBs have become a challenge for theoretical models

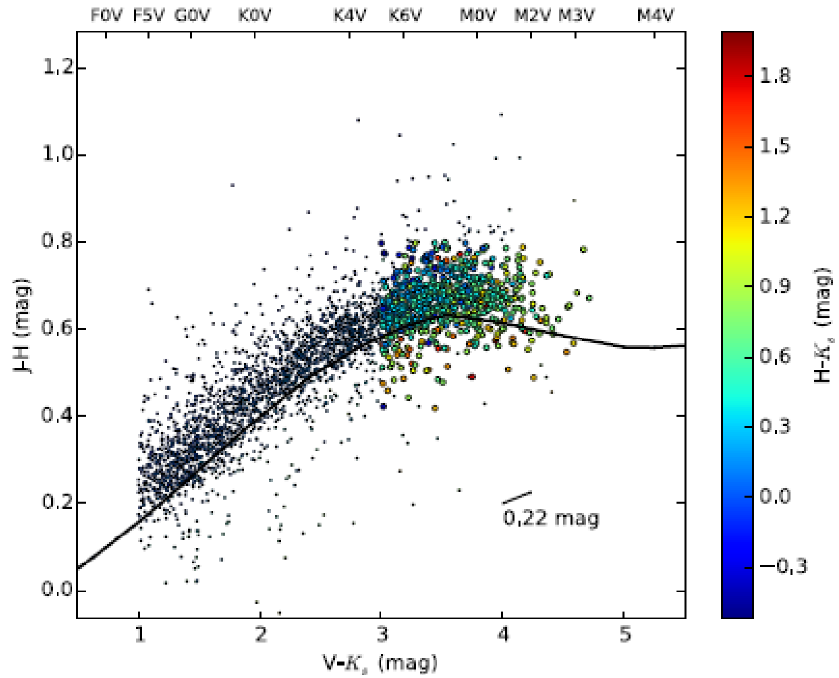
Impose color criteria
V−Ks>3.0 (Hartman et al.2011)
0.35<J−H<0.8 mag and H−Ks<=0.45 mag (Lépine & Gaidos 2011; Zhong et al. 2015).

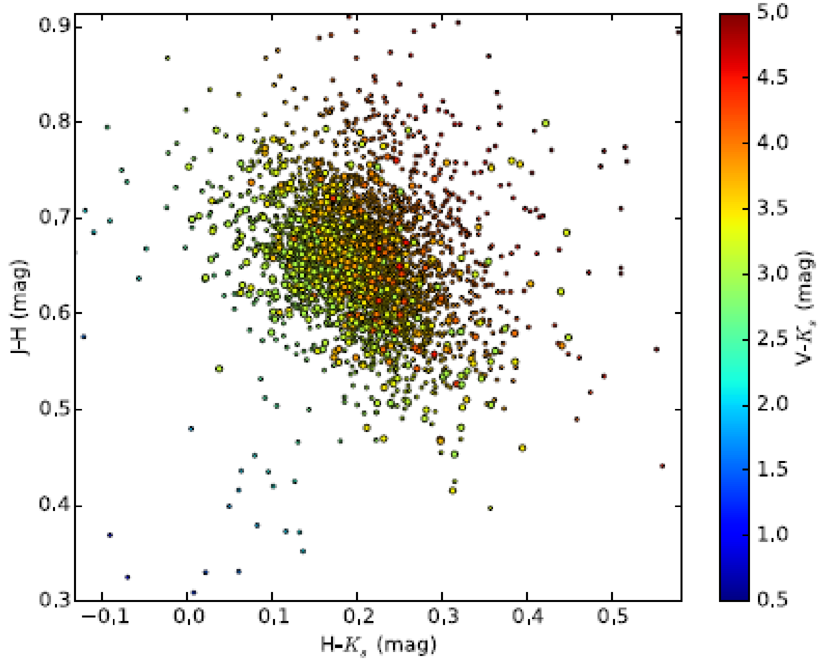
$$V = V_{\rm CSS} + 0.31 \times (B - V)^2 + 0.04.$$

2MASS JHK photometry, performing a cross-match to the 2MASS catalog (Cutri et al. 2003) within 3” of the positions of our stars. Available , photometry from the APASS survey (Henden et al. 2016) was also used, to obtain the (B − V) color index

No visual color information
transformation from 2MASS indices to the Johnson-Cousins system (Bilir et al. 2008, their Equation (16))+ Interstellar extinction corrections E(B − V) values (Green et al. 2015).

609 low-mass EB candidates K5-M3 M<0.71 $M_{\odot}$ and with errors <0.1 $M_{\odot}$





Tests

1. $(V - K_s) - (J - H)$ color–color diagram of the 3456 CSS EBs classified as D and the theoretically expected colors of main-sequence F5-M3 stars (Pecaut & Mamajek 2013).
The large dots refer to the 609 low-mass EB candidates.

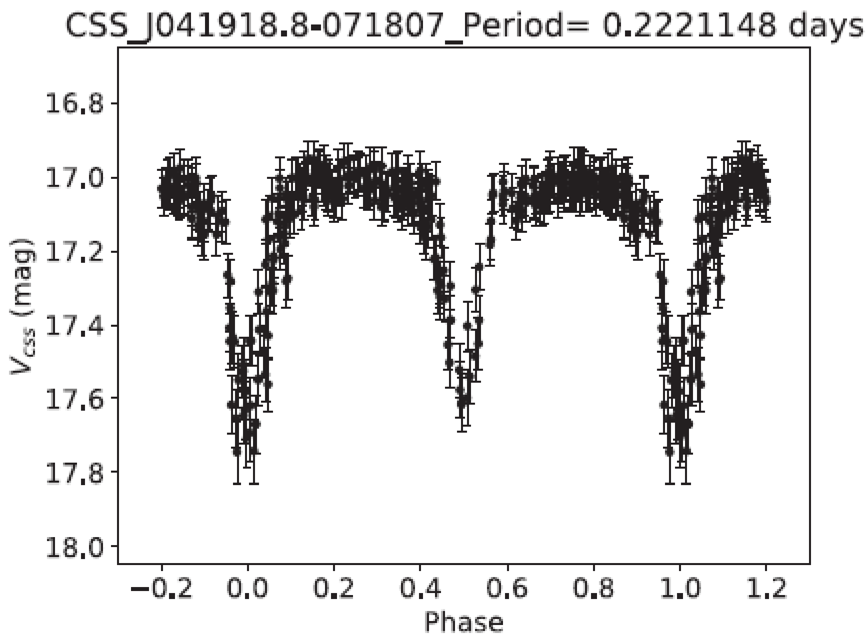
The reddening vector was calculated from the mean value of the extinction of the entire sample, while the range is within [0.01–0.59]mag

2. $(H - K_s) - (J - H)$ color–color diagram of **609 low-mass EB candidates (large dots)** overplotted on the sample of low-mass stars from the LAMOST survey (smaller dots).

In both panels, the different colors indicate the color index value according to the adjacent color bar.

- **72 were matched with Table 1 of Lee (2015)**
- **4 systems have been verified as double-lined M-dwarf EBs (Lee & Lin 2017; Lee 2017)**

Rare EA systems with periods close to the period cutoff at P~0.22 day (Rucinski 1992, 1997)



Only a few such systems are currently known (Drake et al. 2014a).

Do we know another detached system with main-sequence components and short P?

GSC 2314-0530 (=1SWASP J022050.85+332047.6) with 0.1926 day, identified by Norton et al. (2007) and modeled by Dimitrov & Kjurkchieva (2010). Nefs et al. (2012) spectroscopically confirmed a detached system with a 0.18day period containing an M dwarf, but without measuring radial velocities

Table 1
CRTS EA Systems

Name	ID	R.A. (h:m:s)	Decl. (° : ′ : ″)	MJD[a] (days)	Per (days)	$\langle V_{err} \rangle$[b] (mag)	Npoints	Class	LMCand	LongTerm
CSS_J235945.5+303731	11291130655	23:59:45.5	+30:37:31.8	54265.53875	2.68651	0.0138	391	D	···	···
CSS_J235856.7+371823	11381030196	23:58:56.7	+37:18:23.5	55062.35518	1.35464	0.0136	312	D	···	···
CSS_J235816.7+293325	11291130352	23:58:16.7	+29:33:25.3	53537.41966	0.72949	0.0457	390	SD	···	···
CSS_J235756.9–023247	10011280051	23:57:56.9	−02:32:47.2	54747.25303	1.74457	0.0133	325	N/A	···	···

Physical Parameters of Northern Eclipsing Binaries in the Catalina Sky Survey

Athanasios Papageorgiou[1,2], Márcio Catelan[1,2,3,6], Panagiota-Eleftheria Christopoulou[4], Andrew J. Drake[5], and S. G. Djorgovski[5]
[1] Pontificia Universidad Católica de Chile, Facultad de Física, Instituto de Astrofísica, Av. Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile
apapageo@astro.puc.cl
[2] Millennium Institute of Astrophysics, Santiago, Chile
[3] Centro de Astro-Ingeniería, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile
[4] Department of Physics, University of Patras, 26500, Patra, Greece
[5] California Institute of Technology, 1200 East California Boulevard, Pasadena, CA 91225, USA
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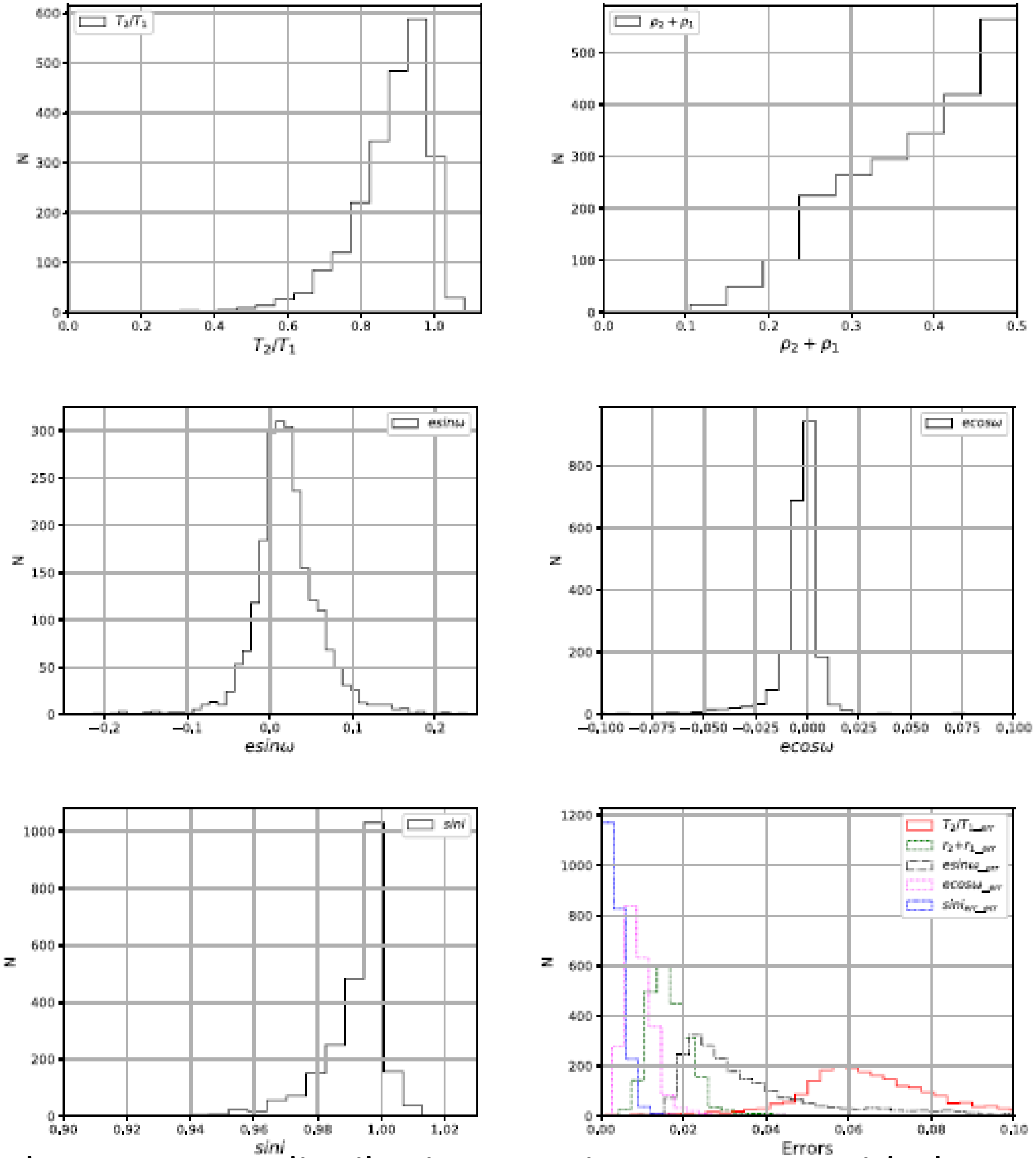
Estimation of Physical parameters (T_2/T_1, $\rho_2+\rho_1$, *e*sin *ω*; *e*cos *ω* and sin *i*), where e is the eccentricity, ω is the argument of periastron, and i is the orbital inclination **for 2281 CSS EBs with** EA-type light-curve (LC) morphology

via Artificial Intelligence (EBAI) artificial neural network (ANN) tool (Prša et al. 2008; Guinan et al. 2009) .
An intensive search for the optimal ANN topology was performed.

Two independent methods to feed the ANN with LCs that are representative of the CSS observations, **TeMPLate fitting (TMPL; Layden 1998) and the Two-Gaussian Model (TGM; Mowlavi et al. 2017)** novel

Parameter uncertainties -Monte Carlo approach

(not discuss here the construction of the training/validation sets, the parameter optimization of the ANN, the validation, and recognition procedures)



The majority of the systems have circular orbits

T_2/T_1 ~1, a fast drop-off of the sin *i (to* exhibit eclipses)

257 detached double-lined EBs in the Milky Way collected by Eker et al. (2014)

1540 EBs (outside of the EBAI training limits) with parameters derived solely on the basis of the best-matching template

The parameter distributions are in agreement with the results presented by Prša et al. (2008, 2011a) for detached systems

Table 2
Physical Parameters of 2281 EBs Derived from EBAI ANN

Name	$\frac{T_2}{T_1}$	$\frac{T_2}{T_1}_{err}$	$\rho_1 + \rho_2$	$\rho_1 + \rho_{2err}$	$e \sin \omega$	$e \sin \omega_{err}$	$e \cos \omega$	$e \cos \omega_{err}$	sin [illegible]	[illegible] i_{err}
CSS_J235856.7+371823	0.8699	0.0466	0.4978	0.0182	0.0388	0.0297	0.0017	0.0117	[illegible]	[illegible]79
CSS_J235715.5+305455	1.0382	0.0524	0.2648	0.0249	0.0020	0.0785	−0.0038	0.011[illegible]	[illegible]	[illegible]
CSS_J235444.8+305751	0.9395	0.0475	0.4750	0.0079	−0.0464	0.0175	0.0104	[illegible]	[illegible]	[illegible]
CSS_J235227.0+395515	1.0128	0.0198	0.4799	0.0129	0.0994	0.0184	−0.0129	[illegible]	[illegible]	[illegible]
CSS_J235151.3+035409	0.6197	0.0690	0.3921	0.0108	0.0486	0.0237	−0.0[illegible]	[illegible]	[illegible]	[illegible]
CSS_J235104.0+115651	0.9194	0.0691	0.4504	0.0219	0.0315	0.0249	[illegible]	[illegible]	[illegible]	[illegible].0068
CSS_J234850.3+133300	0.7064	0.1198	0.2656	0.0119	0.0539	0.0609	[illegible]	[illegible]	[illegible]	0.0013
CSS_J234826.5+271203	0.9434	0.0624	0.3950	0.0186	0.0102	[illegible]	[illegible]	[illegible]	[illegible]35	0.0036
CSS_J234734.4+203331	0.7487	0.0725	0.3487	0.0115	0.0311	[illegible]	[illegible]	[illegible]	0.9996	0.0012
CSS_J234700.0+180015	0.9843	0.0751	0.2690	0.0247	−0.08[illegible]	[illegible]	[illegible]	[illegible]	0.9887	0.0043

Table 3
Physical Parameters of 1540 EBs Deri[illegible]

Name	ID	R.A. (h:m:s)	D[illegible]	[illegible]	[illegible]	[illegible]	[illegible] ω	$e \cos \omega$	$\sin i$	Flag
CSS_J235816.7+293325	1129113035231	23:58:16[illegible]	[illegible]	[illegible]	[illegible]	[illegible]78	0.0005	−0.0001	0.9960	Template
CSS_J234819.9+344833	1135106027985	23:[illegible]	[illegible]	[illegible]	[illegible]	0.5038	0.0000	0.0002	0.9924	Template
CSS_J234439.7+055255	1107126005261	[illegible]	[illegible]	[illegible]	[illegible]	0.7793	−0.0001	0.0001	0.9280	Template
CSS_J234116.3+392234	113810208537[illegible]	[illegible]	[illegible]	[illegible]	[illegible].5424	0.5953	0.0042	−0.0167	0.9703	Template
CSS_J234042.4+045812	110412[illegible]	[illegible]	[illegible]	[illegible]	0.5910	0.6348	0.0003	0.0002	0.9269	Template

[illegible]able 4
[illegible]edicated Studies on Nine EBs Found in the Literature

Name	[illegible]	[illegible]	[illegible]	$\rho_1 + \rho_2$[b]	i (°)[a]	i (°)[b]	$(\frac{T_2}{T_1})$(%)	$(\rho_1 + \rho_2)$(%)	i (°)(%)	References
CSS_[illegible]	[illegible]	[illegible]	[illegible]27	0.447	90.00	88.24	1.02	4.42	2.00	Windmiller et al. (2010)
C[illegible]	[illegible]	[illegible]	0.432	0.429	88.92	85.46	1.90	0.84	4.05	Zhang et al. (2015)
[illegible]	[illegible]	[illegible]	0.418	0.435	84.01	87.46	13.10	3.90	3.94	Zhang (2012)
[illegible]	[illegible]	[illegible].615	0.417	0.499	90.00	87.96	4.52	16.34	2.32	Lacy (2004)
[illegible]	[illegible]	0.602	0.394	0.423	86.72	83.14	35.21	6.75	4.31	Zasche et al. (2014)
[illegible]	[illegible].786	0.600	0.473	0.465	82.12	87.96	31.01	1.84	6.63	Yang (2013)
C[illegible]	0.976	N/A	0.425	0.530	78.05	73.46	N/A	19.80	6.25	Lee & Lin (2017)
CS[illegible]1434	0.988	N/A	0.212	0.240	83.56	83.46	N/A	11.60	0.13	Lee & Lin (2017)
CSS_[illegible]8+344808	1.000	N/A	0.336	0.310	85.15	89.85	N/A	8.42	5.24	Lee & Lin (2017)

Notes.
[a] EBAI.
[b] Literature.

Interesting subsamples : 27% well D with deep eclipses. (Papageorgiou 2018) 22% LM candidates. 3% e>0.05 and deep eclipses . Follow up…
Our database can serve to investigate individual systems at the edge of the general parameter distributions that characterize EBs

3. Period variations (ETVs) (Papageorgiou et al. (*to be submitted in a few days)*

a lot of phenomena …

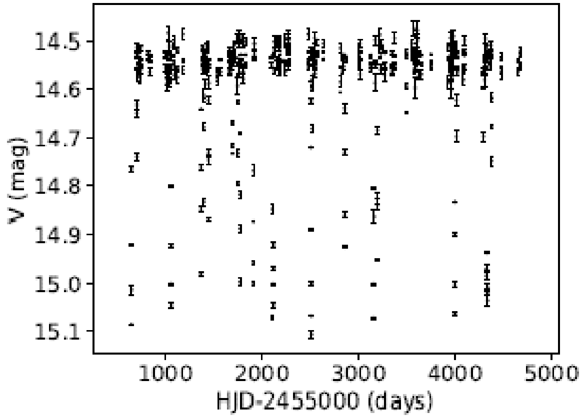
236 systems from the Kepler mission with a timing variation signal compatible with the presence of a third body (Conroy et al. 2014))

2% of the13,927 SuperWASP EBs exhibited cyclic variations (Lohr et al. 2015)

91 EBs from MOA (Li et al. 2018) LTTE P_3=250 d to 28 yr

992 potential hierarchical triple or multiple system candidates exhibiting LTTE by analysing a selection of 80,000 EBs among 425,193 OGLE-IV variables (Hajdu et al.2019)

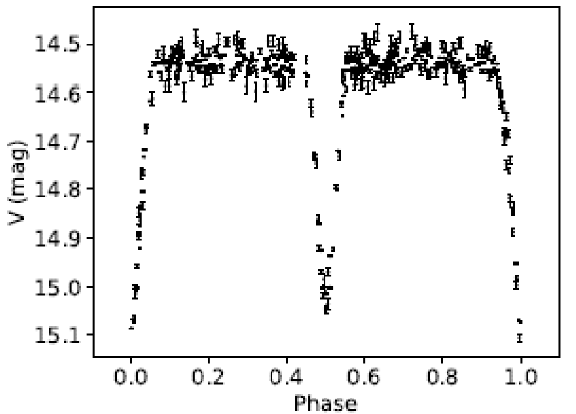
- **Data selection**
- **ToM computation**
  - **tests to check reliability**
- **Analysis of the ETVs**



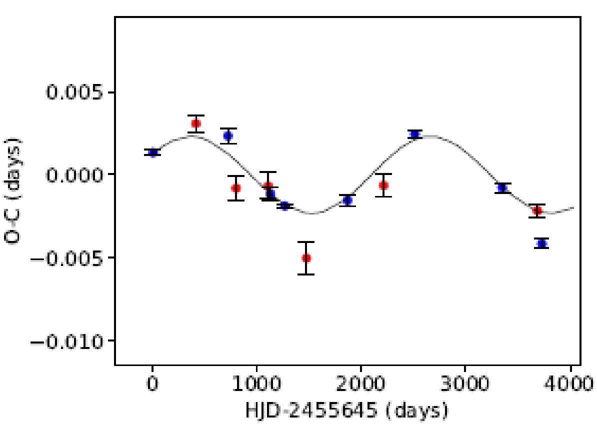
- **ToM computation (binning 300 d, To, P Papageorgiou et al. 2018)**

Gaussian function template (simplex LMFIT) and errors with MCMC

$$f(x) = C + d_i \times \exp\left[-\frac{(x - m_i)^2}{2\, s_i^2}\right]$$

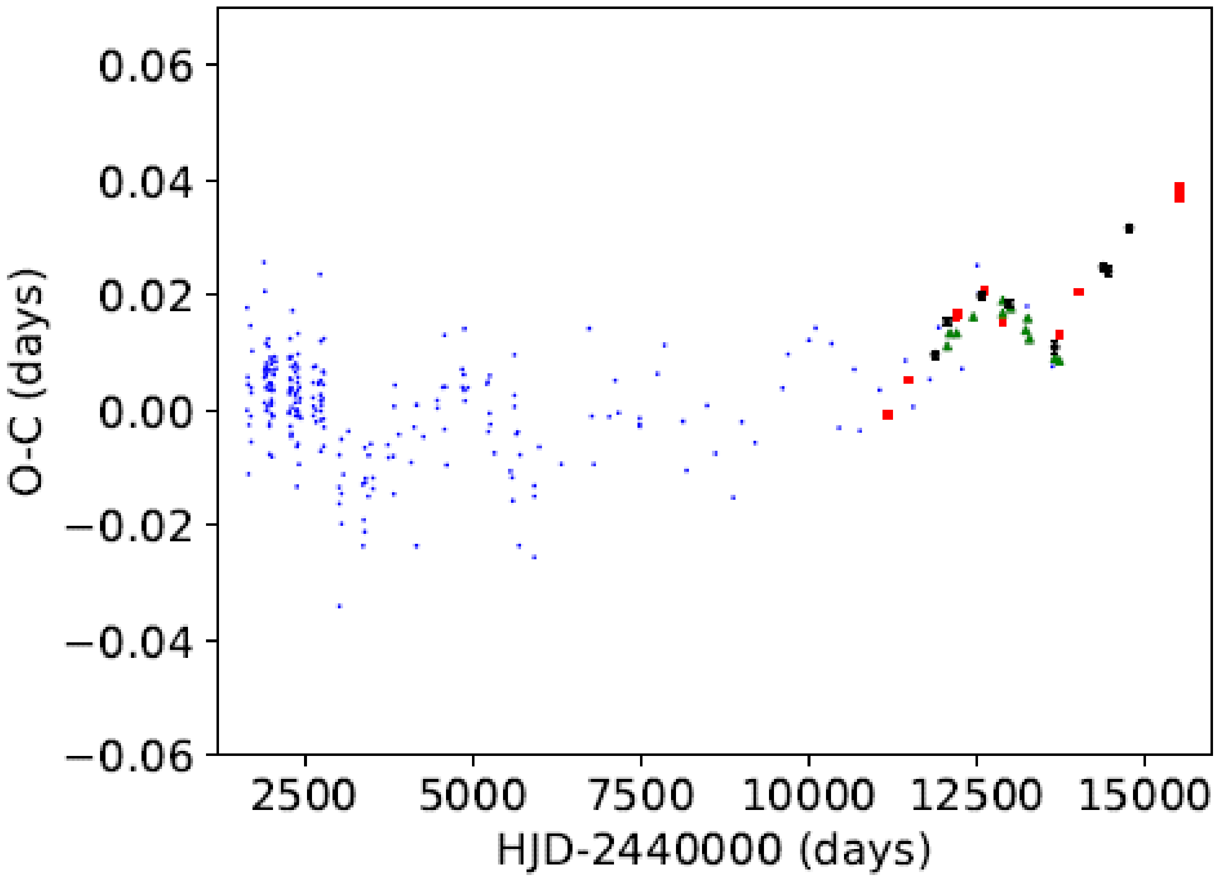


C = constant,
s_i the half-width,
d_i the depth
m_i the phase shift, with i = 1, 2 for the p,s.



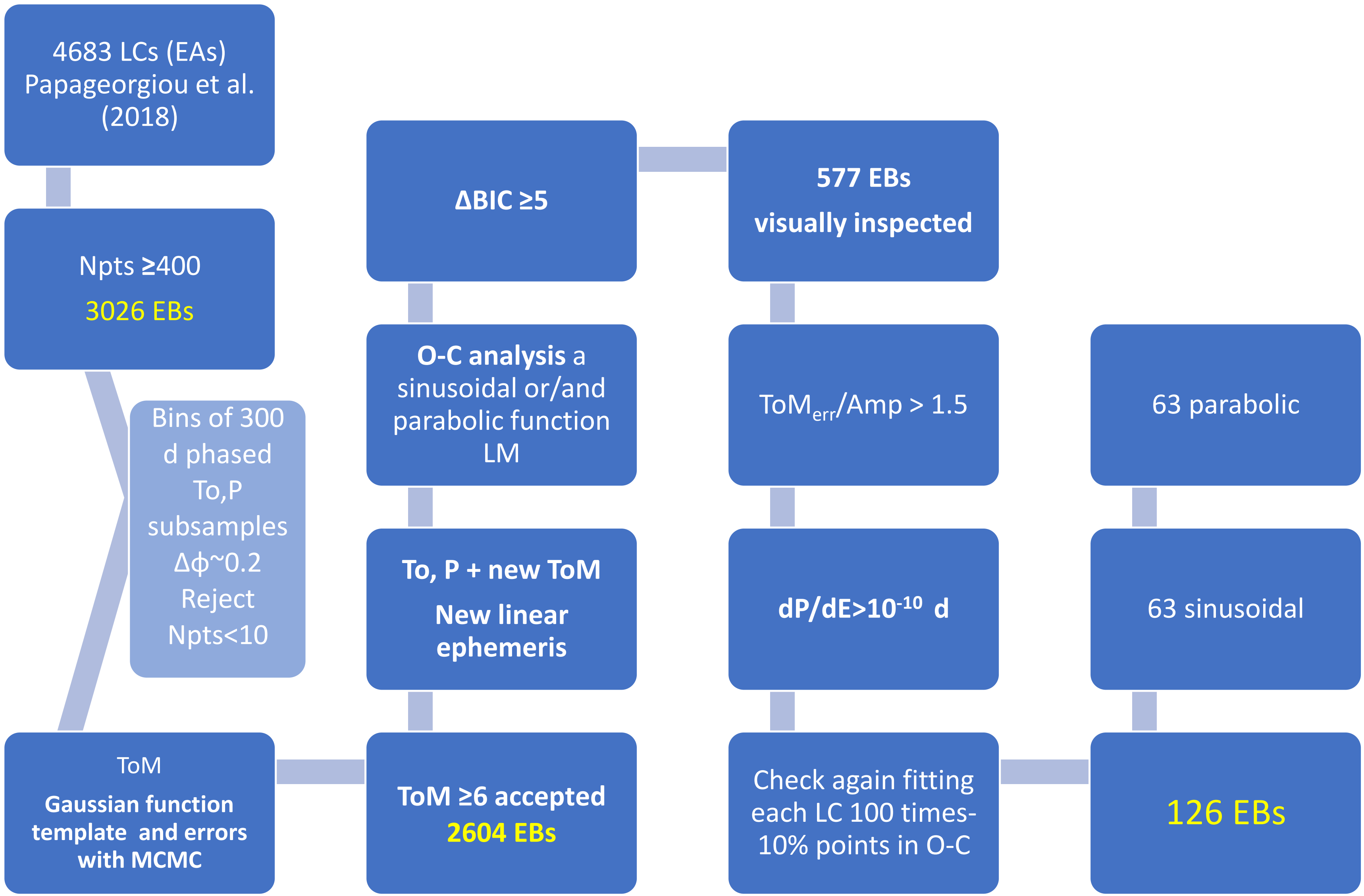
Test on a synthetic EB:
synthetic LCs of a detached EB with period variations, generated using PHOEBE 2.0 (Prša et al. 2016),

Test on the EB star VY Ceti (well known cyclic ETV)



ETVs calculated from the ASAS LC using the template fitting (black circles) along with the minima calculated by Pilecki et al. (2007) (green triangles) and other available minima from the literature (visual data: small blue dots; CCD observations: red squares).

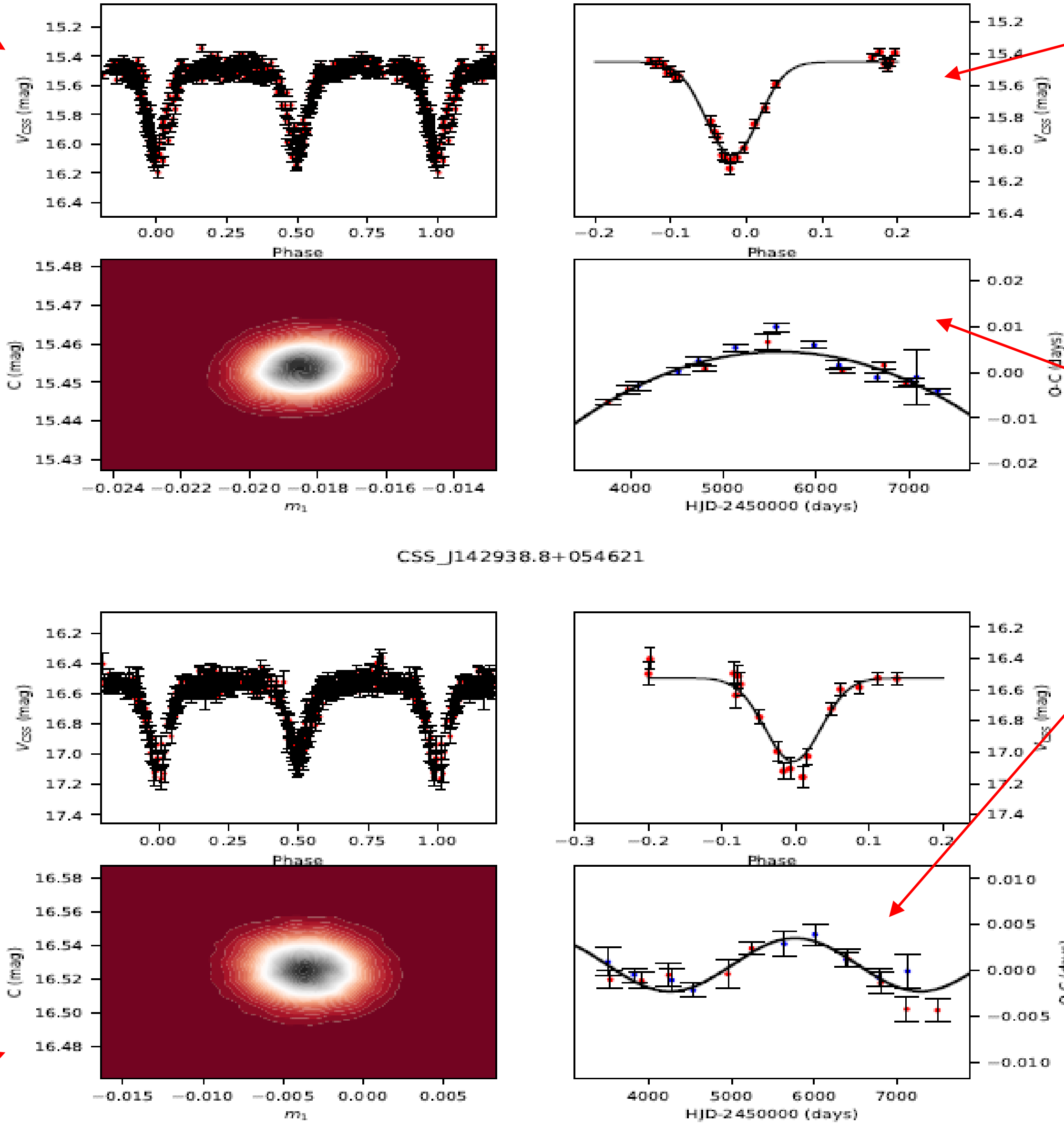
EBs with period variations found in CSS data



EBs with period variations found in CSS data

Folded LC

ToM with a Gaussian function



ETV data together with the sinusoidal or parabolic model

27

Substellar and stellar companions in eclipsing binaries

Konstantinos **Zervas**, A. Papageorgiou, P-E Christopoulou

MCMC procedure in which only the horizontal and vertical shifts (m and C, respectively) were adjusted

126 EBs with significant period changes

- **63 CSS EBs with cyclic ETV**

$Amp_{\rm mod}$ (d)	$(Amp_{\rm mod})_{err}$ (d [−, +])	$Per_{\rm mod}$ (yr)	$(Per_{\rm mod})_{\rm err}$ (yr [−, +])

- **63 CSS EBs with quadratic ETV**

$\frac{dP_{\rm bin}}{dE}$ (days cycle^{-1} $\times 10^{-10}$)	$\left(\frac{dP_{\rm bin}}{dE}\right)_{\rm err}$ (days cycle^{-1} $\times 10^{-10}$[−, +])

Parameter errors, synthetic O- C diagrams
MC simulations (three models : linear, parabolic, sinusoidal 1,000 times for each individual EB)

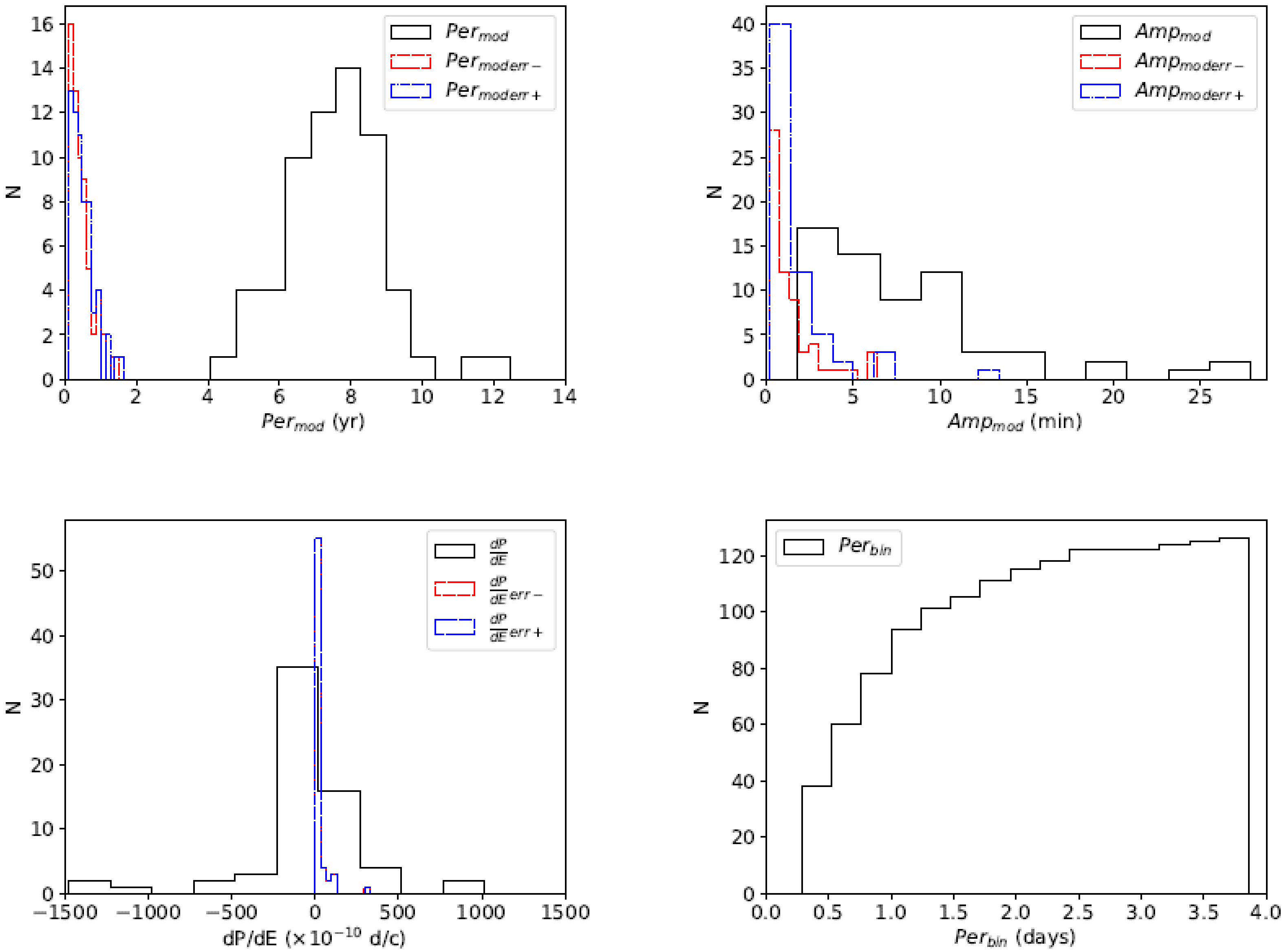


Figure 5. Distributions of the period modulation $Per_{\rm mod}$ (top left), amplitude $Amp_{\rm mod}$ (top right), period change rate $\frac{dP_{\rm bin}}{dE}$ and MC-based errors (bottom left), and cumulative distribution of the binary period $P_{\rm bin}$ (bottom right) of CSS EBs.

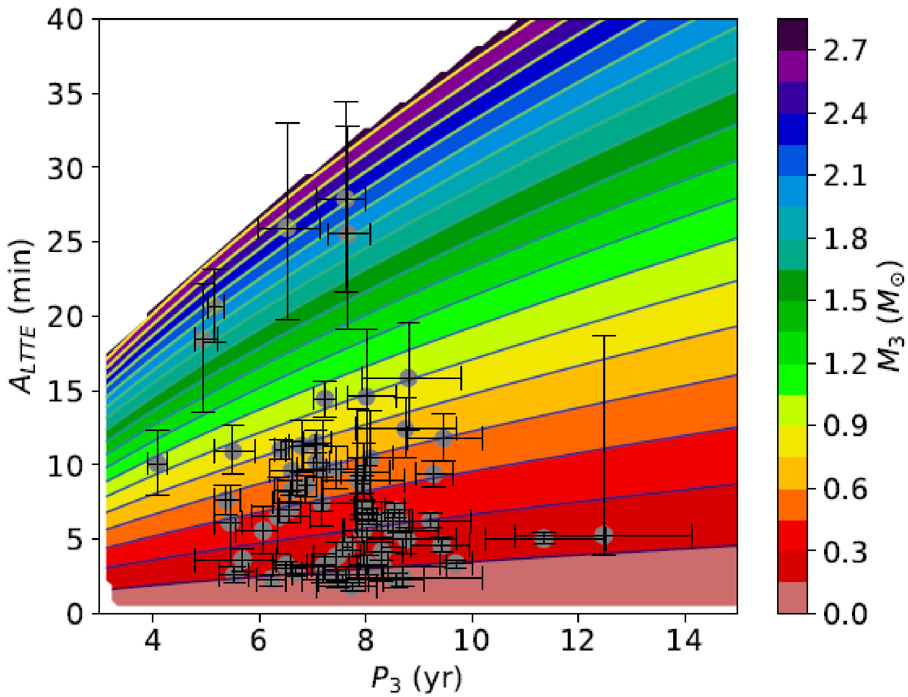
For the 63 triple candidates **LTTE ?**

1) calculated minimum masses of the tertiary companion (M3)

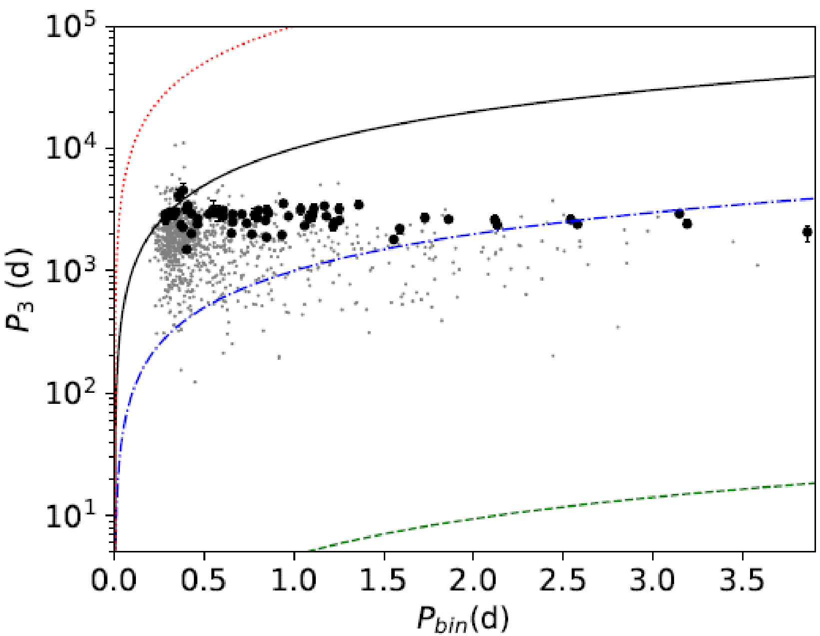
$$f(M_3) = \frac{4\pi^2 \alpha_{12}^3 \sin^3 i_3}{G P_3^2} = \frac{M_3^3 \sin^3 i_3}{(M_{12} + M_3)^2},$$

$$A_{\rm LTTE} = \frac{\alpha_{12} \sin i_3}{c} \sqrt{1 - e^2 \cos \omega_3}.$$

$M_3 < 0.6\ M_\odot$ and $A_{\rm LTTE}$ amplitude 5-10 min



2) P_3=f(P_{bin}) 992 OGLE-IV potential triple candidates (Hajdu et al. 2019)



Applegate?

$$\frac{\Delta P_{\rm bin}}{P_{\rm bin}} = \frac{4\pi \times Amp_{\rm mod}}{Per_{\rm mod}} = 10^{-6} - 10^{-7}$$

(Wolf et al. 2016; Zhang et al. 2018; Bin et al. 2019).

Starspot activity?

We cannot know a priori if the parabolic variation represents part of a sinusoidal variation, i.e., a potential LTTE signal with a period longer than the timespan of our data (12 yr).

We exploited the entire sample of 4683 Algol-type EBs from CSS and

- revised periods and class
- derived the phenomenological and physical parameters (EBAI, TMPL).
- search for systems exhibiting long-term variation, that potentially harbor low-mass components
- Searched for low-mass EBs
- Searched for period variation

Out of the 63 systems that appear to exhibit periodic ETVs, 19% are low-mass candidates

These should be considered for follow-up observations and systematic study further research to

- clarify the nature of ETVs and possibly detect tertiary companions;this can be accomplished with further light curve analysis, spectroscopy, astrometry, or direct high-resolution imaging.
- Extension of the eclipse time data sets via new photometric observations will give the opportunity to apply the analytical formula of Irwin (1959) that takes into account the eccentricity of the system

16:20-16:40 **Lalounta** et al.

An investigation of Low Mass Ratio EW systems from Catalina Sky Survey

Thank you for your attention

P-E Christopoulou Univ. of Patras, Greece