AN INVESTIGATION OF LOW MASS RATIO EW SYSTEMS FROM CATALINA SKY SURVEY

Lalounta E.[1], Papageorgiou A.[2,3], **Christopoulou P.-E.[1]**
Catelan M.[2,3]

[1]Department of Physics, University of Patras, Greece
[2] Pontificia Universidad Católica de Chile, Santiago, Chile
[3] Millennium Institute of Astrophysics, Santiago, Chile

UNIVERSITY OF PATRAS
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ

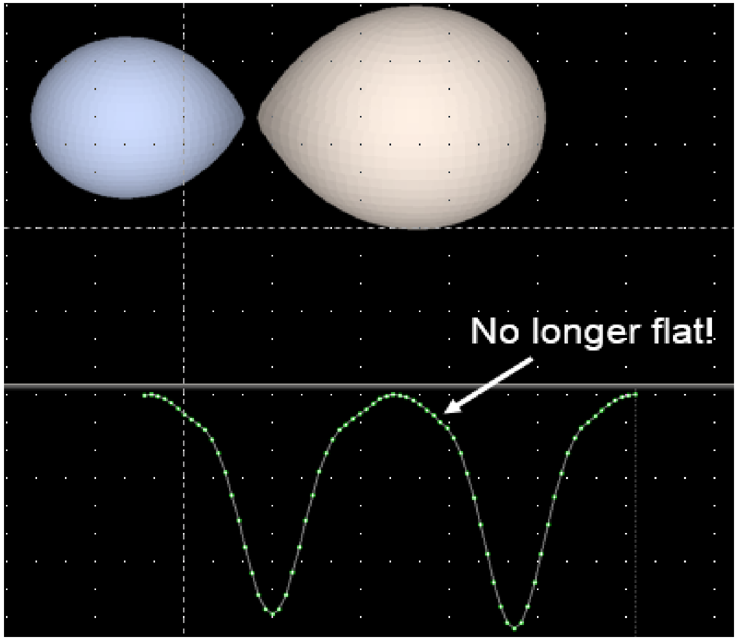
INSTITUTO MILENIO DE ASTROFÍSICA

EW SYSTEMS

- Systems in physical contact: $\Omega_1 = \Omega_2 = \Omega$=pot & $\Omega_{in}>\Omega>\Omega_{out}$, thus $0<f<1$, where $f = \dfrac{\Omega - \Omega_{in}}{\Omega_{out} - \Omega_{in}}$
- Different masses almost equal T_{eff}
- A-type ($M_2/M_1<1$ & $T_2/T_1<1$) or W-type ($M_2/M_1<1$ & $T_2/T_1>1$)
- $0.22 < P < 1$ day

Rucinski (1992)

- A, F, G, K s.t.



Importance of Low Mass Ratio (LMR) EWs

- $M_2/M_1 \leq 0.25$ ⇨ LMR

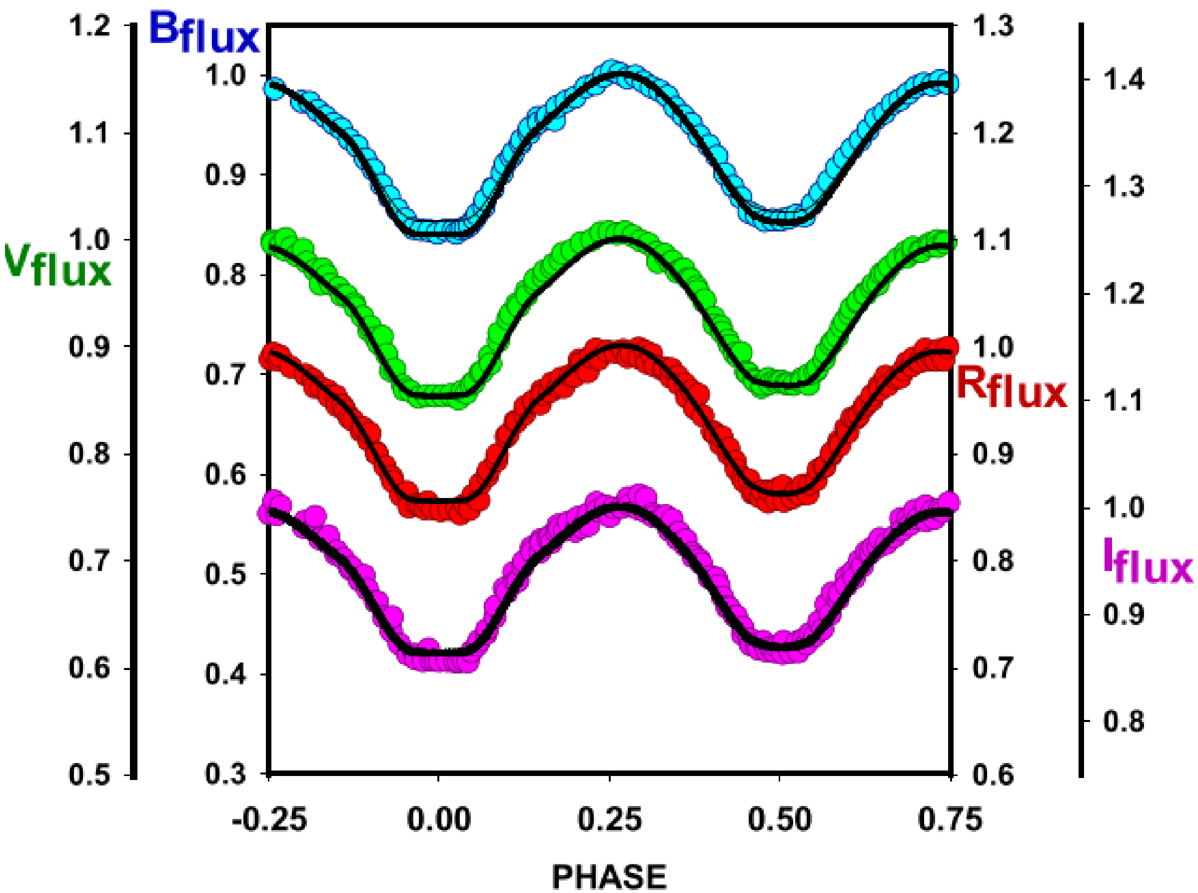
- $M_2/M_1 \leq 0.25$ & FF ≥ 50% ⇨ Deep Low Mass Ratio (DLMR) EWs

$$J_{orb} < 3(J_{1,spin} + J_{2,spin}),$$ (Darwin instability):

  - q_{min} =0.070-0.109 (Rasio 1995, Li & Zhang 2006, Arbutina 2007, 2009 etc)

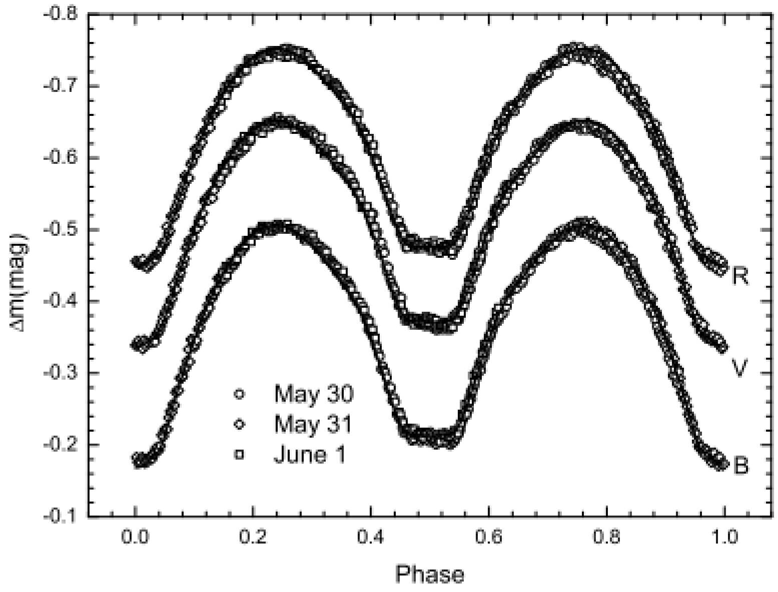
- ***But…the observational data challenge the theory***

V1187 Her
the lowest q, so far…
q=0.04 & i=66.7°
(Caton et al. 2019)

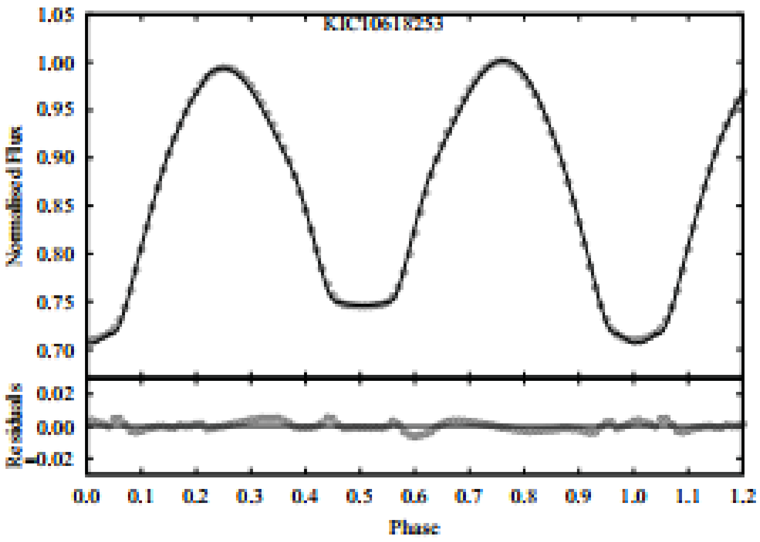


LMR EW systems
LC morphology

EF Dra
q=0.160 & i=78.00°
(Yang 2012)



KIC10618253
q=0.125 & 82.65°
(Şenavci et al. 2016)



The idea…

- Take advantage of the LC morphology to find LMR EW systems in Catalina Sky Survey (Drake 2014)

The tool…

- Fourier decomposition of LCs according to:

$$m(t) = A_0 + \sum_{i=1}^{10} [a_i \sin(2\pi i \phi(t)) + b_i \cos(2\pi i \phi(t))] \quad (1)$$

(Deb & Singh 2009)

Method…

- Gather all the available LCs (44) in V band of the confirmed LMRs from the literature:

1. Phase & normalized flux diagrams
2. Fourier coefficients (eq.1)

- 30592 EW LCs from Catalina Sky Survey (Drake et al. 2014):

1. Clean LCs by 3sigma clipping
2. Epoch determination, phase & normalized flux diagrams
3. Fourier coefficients (eq.1)

- ***b_8,*** b_6, b_9, b_{10} Fourier **cosine** coefficients

Identification

30592 EW systems from CSS

Fourier Decomposition (FD)

2101 LMR candidates

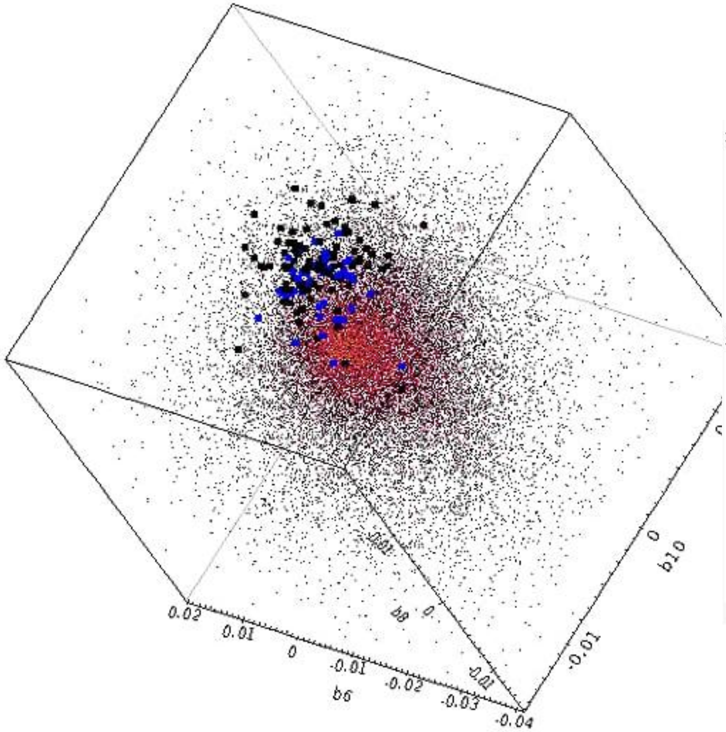
Visual inspection of the LCs-flag 1

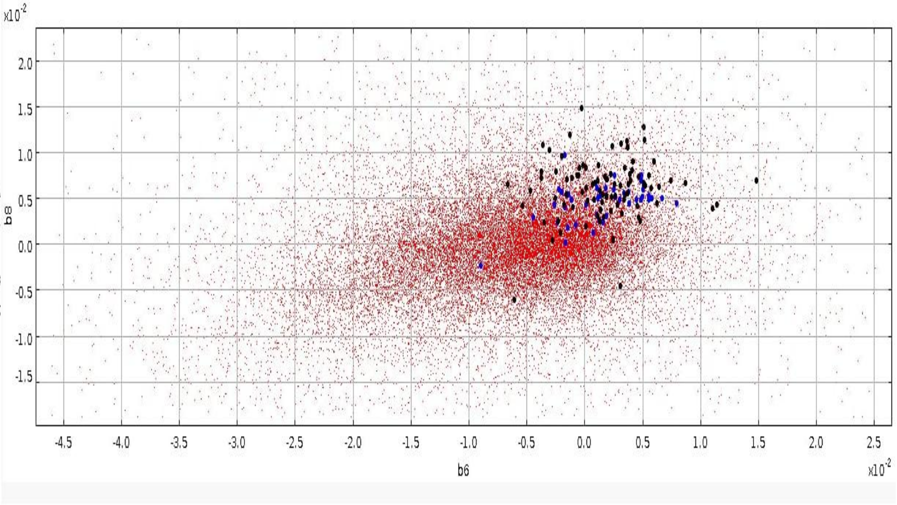
167 LMR candidates LMR EW systems

Visual inspection of the LCs-flag 2

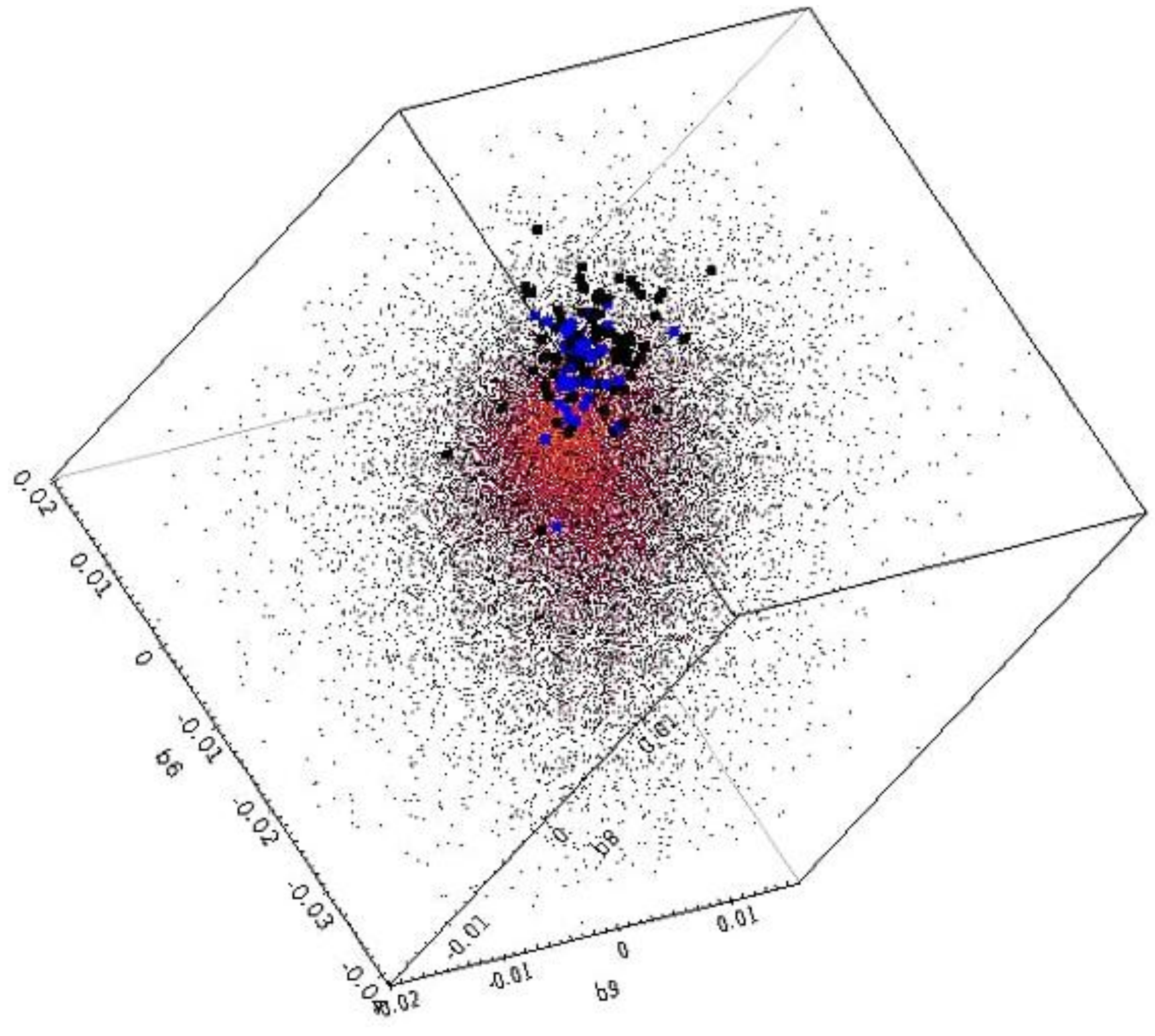
92 candidates LMR EW systems

$b_6b_8b_{10}$
Literature (blue points) & 92 LMR suspected systems (black points)





$b_6b_8b_9$
Literature (blue points) & 92 LMR suspected systems (black points)



For the 92 LMR candidates…

- Search for systems' temperatures:

1. Cross match with Marsh et al. (2016) catalog (52 EW systems)

2. Average from Gaia (DR2) & J-H (Cutri 2003)

- Consider $T_{system}=T_1$ (see next step)

Initial models for PHOEBE-0.31a scripter (Prša & Zwitter 2005)

- Clean LCs :
  1. mode = overcontact binary not in thermal contact
  2. $q = 0.1$
  3. incl = 80°
  4. $T_1 = T_{syst}$
  5. $A_{1,2} = 0.5$ & $g_{1,2} = 0.32$ & $F_{1,2} = 1$
  6. LD coefficients Van Hamme tables (logarithmic law)
- Refine periods & epochs

qi scan script

- T1, q, incl **fixed**
- T2, pot(pot1=pot2), L **free**

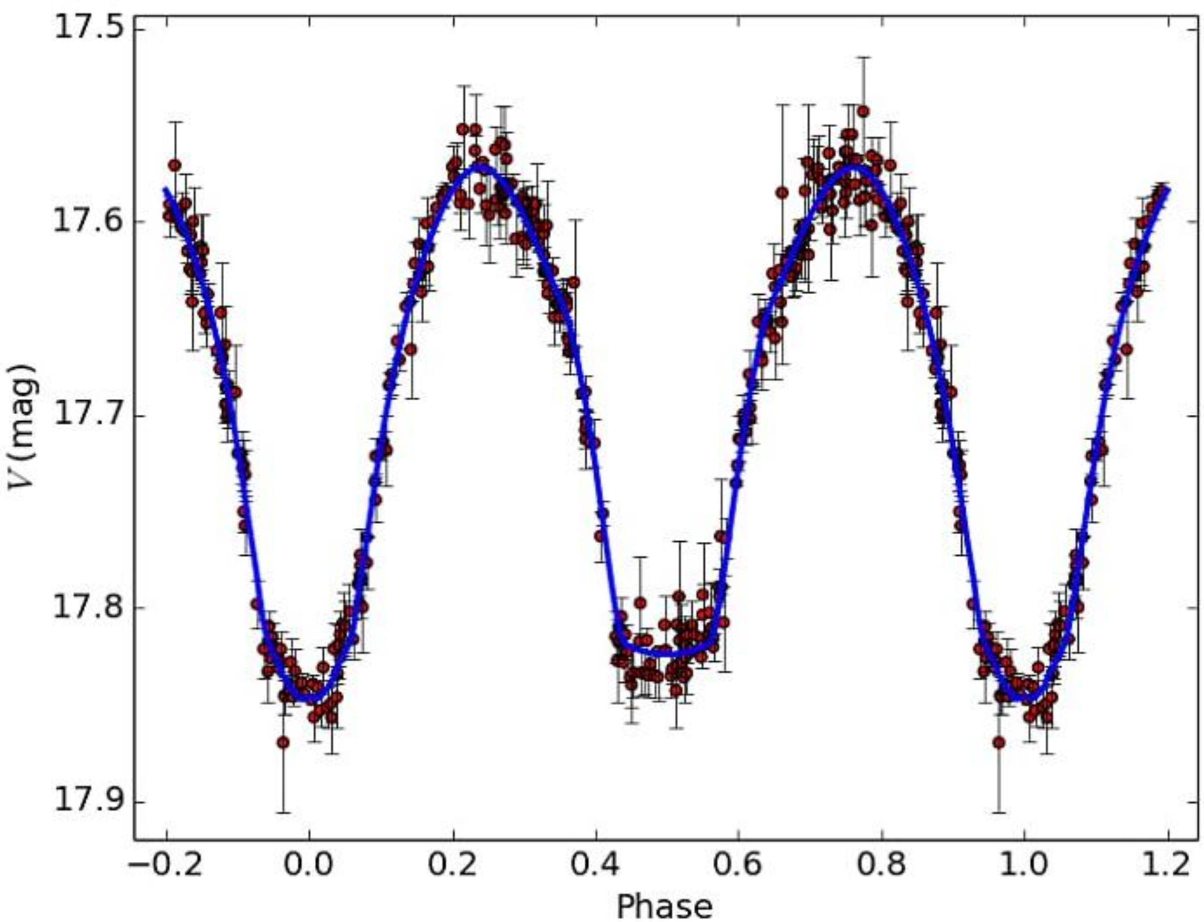
- 2D grid search:

1. q = [0.1-0.6] with q_{k+1}-q_k = 0.05 &
incl = [68° -90°] with $incl_{k+1}$-$incl_k$=1° } **(q_{min},$incl_{min}$)**
2. q = [(q_{min}-0.05)-(q_{min}+0.05)] with q_{k+1}-q_k = 0.01 &
incl = [68° -90°] with $incl_{k+1}$-$incl_k$=1°

Final solution best (min chi2) q-incl pair as initial values

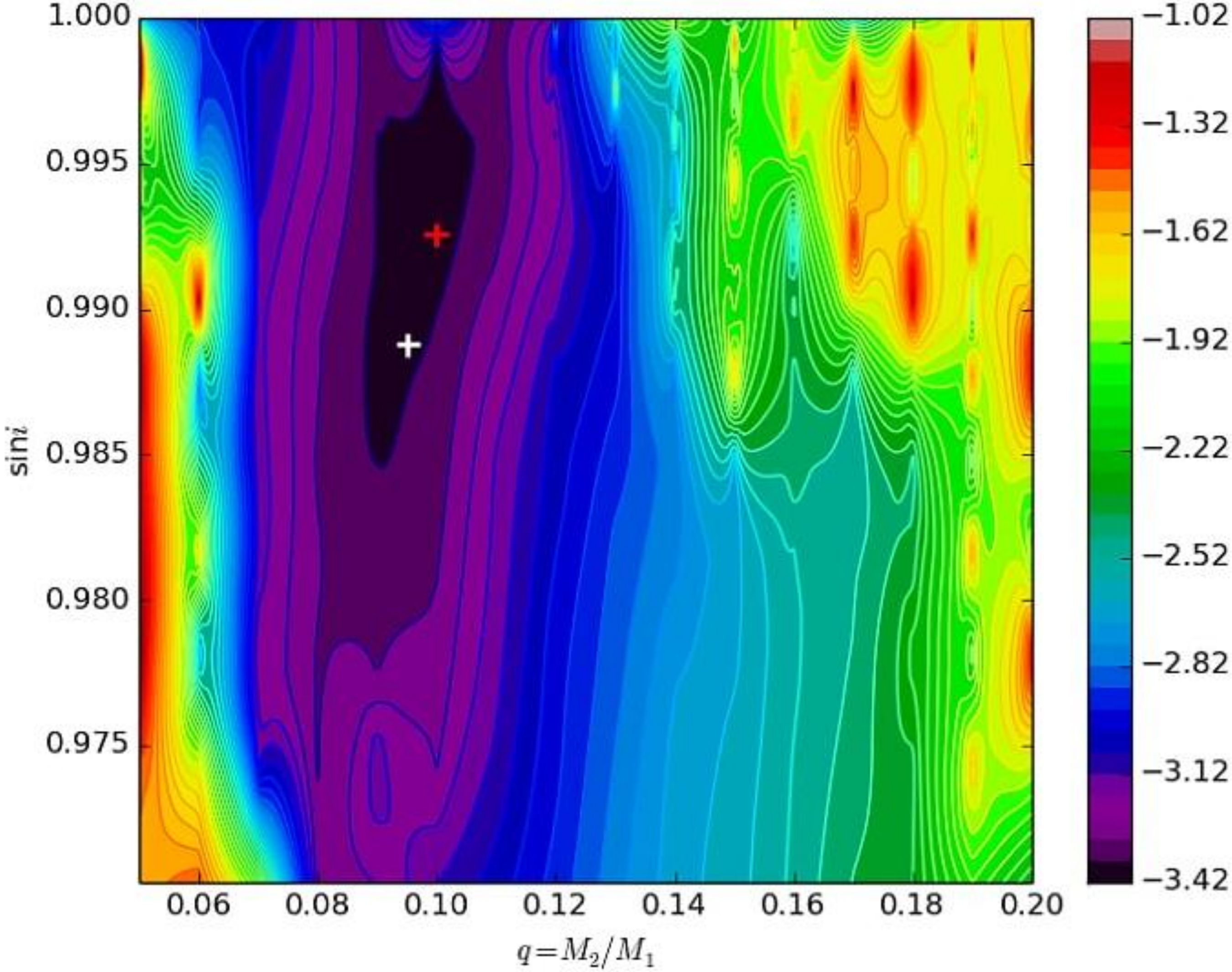
Testing the method

Synthetic LC with q = 0.096, incl=81.4° &
Verror≈0.01 & Npoints≈350



final solution
q = 0.1 &
incl=83°

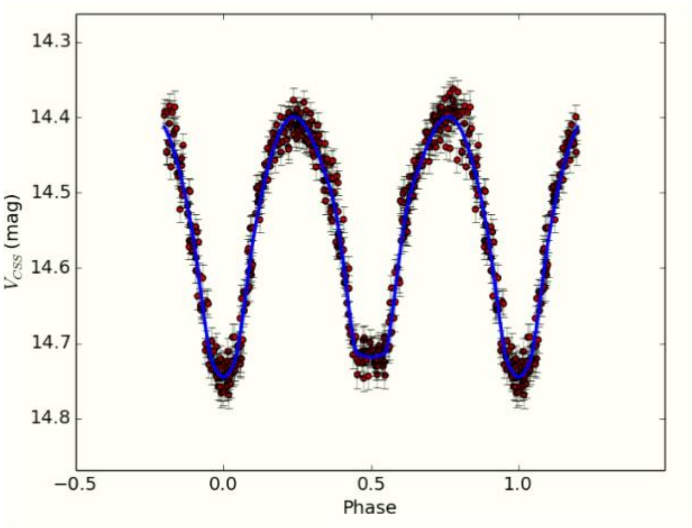
White cross→ (0.096, sin81.4) real solution
red cross → (0.10, sin83) qi scan best solution

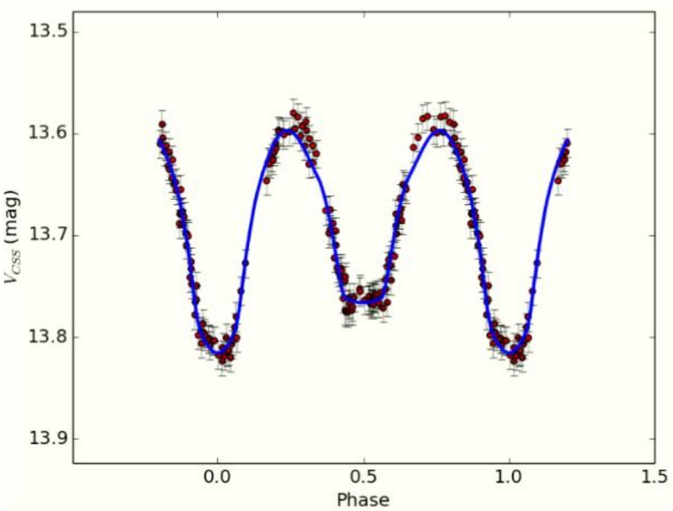


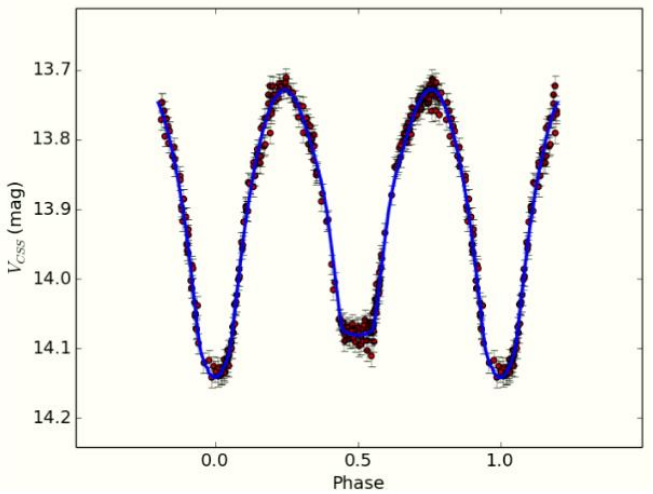
FINAL CATALOG

Created a final catalog with the physical parameters (incl, T_2/T_1, R_2/R_1, FF, HJD0 & Per) of 92 **new** LMR EWs

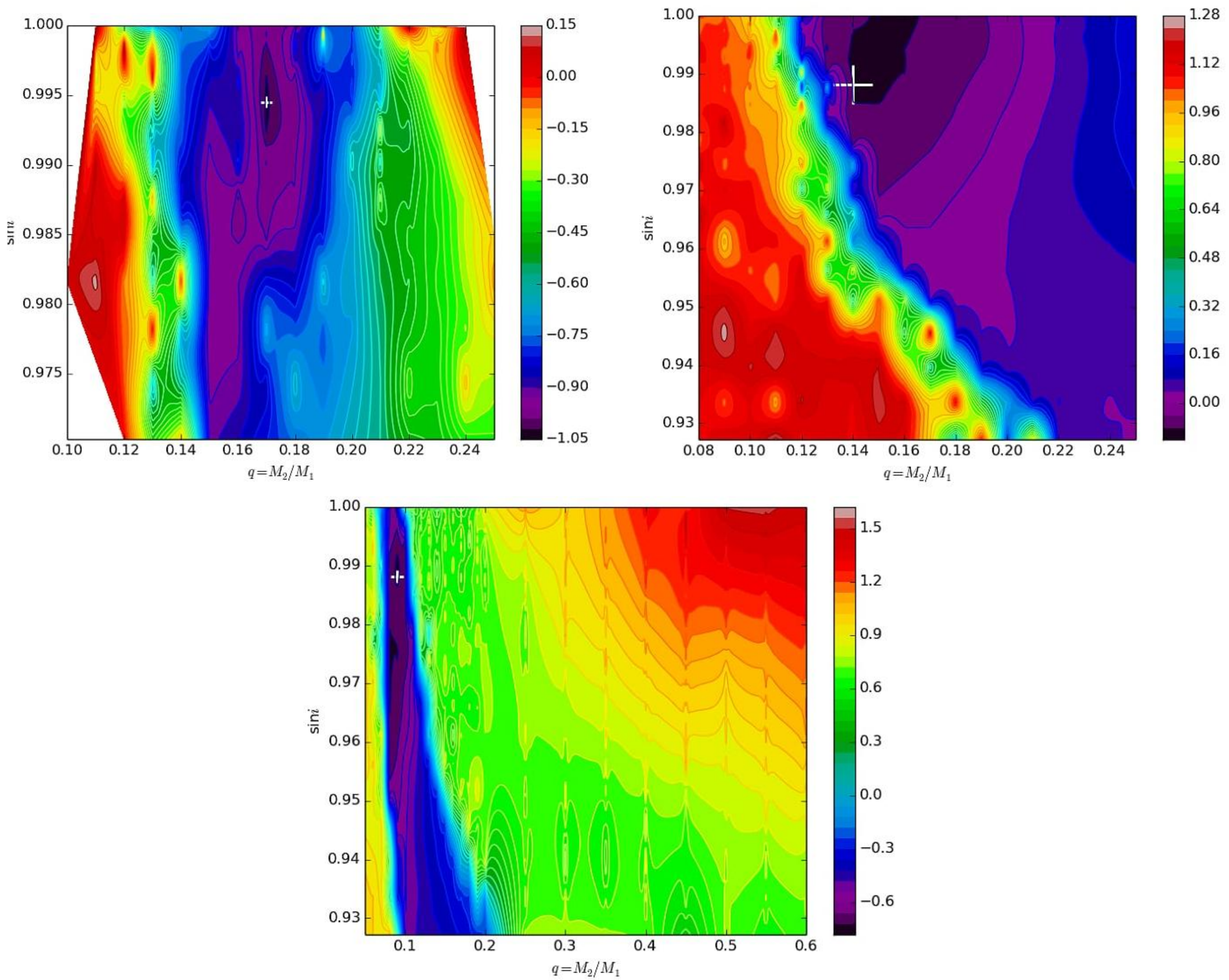
Performance in CSS data







Performance in CSS data

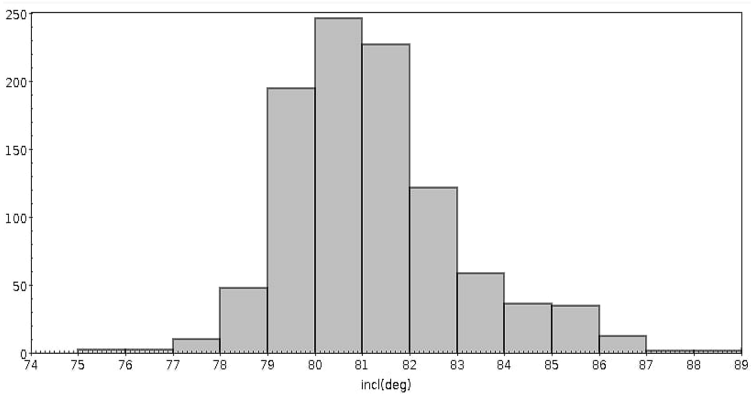


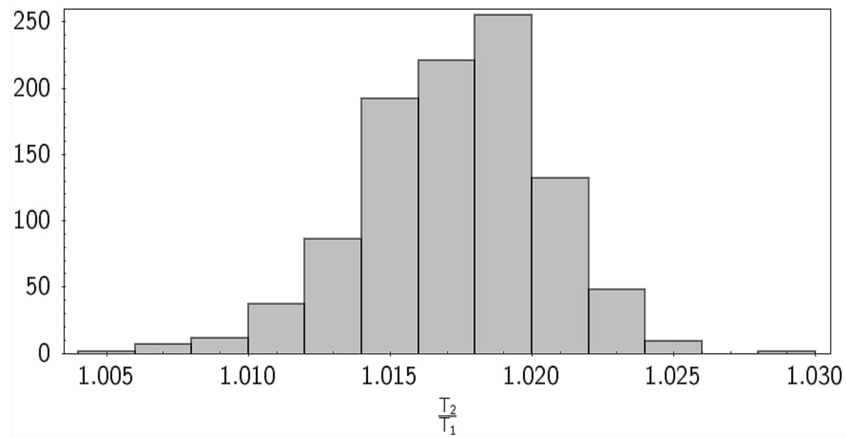
Error budget-Monte Carlo simulation

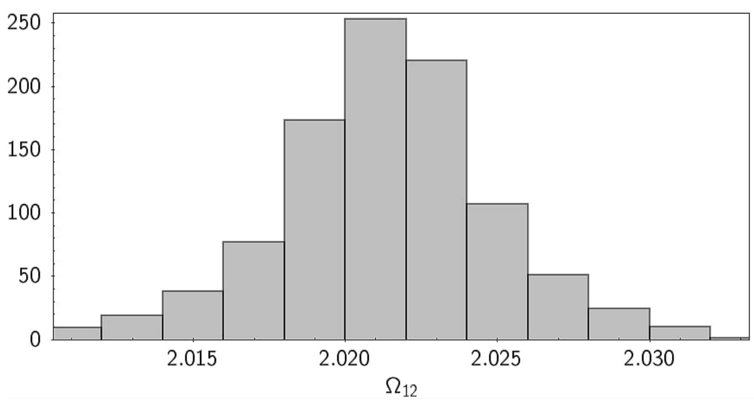
For each system

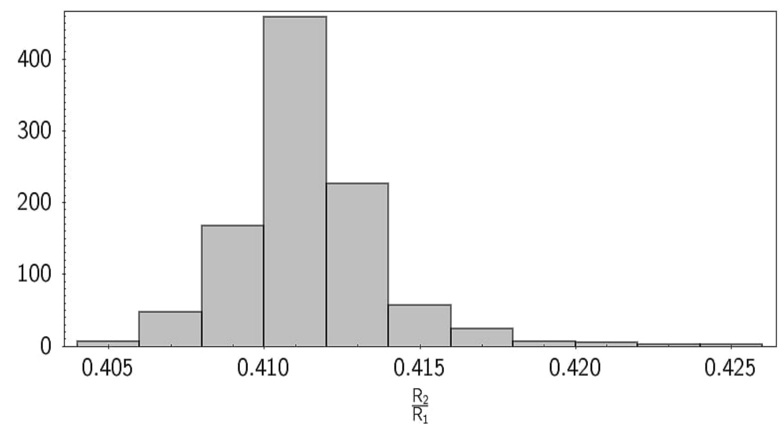
- Start loop:
  - Create synthetic LC from the observed LC
  - Fit the synthetic LC by adjusting T2, pot, L & incl (T_1=T_{eff} & q_{min} fixed)
- End of loop
- Run 1000 x loop
- Extract the lower and the upper bound of error from the 16^{th} and 84^{th} quartile **of each parameter distribution** (T2/T1, R2/R1, pot1, incl)

Example of the parameters distribution for one system

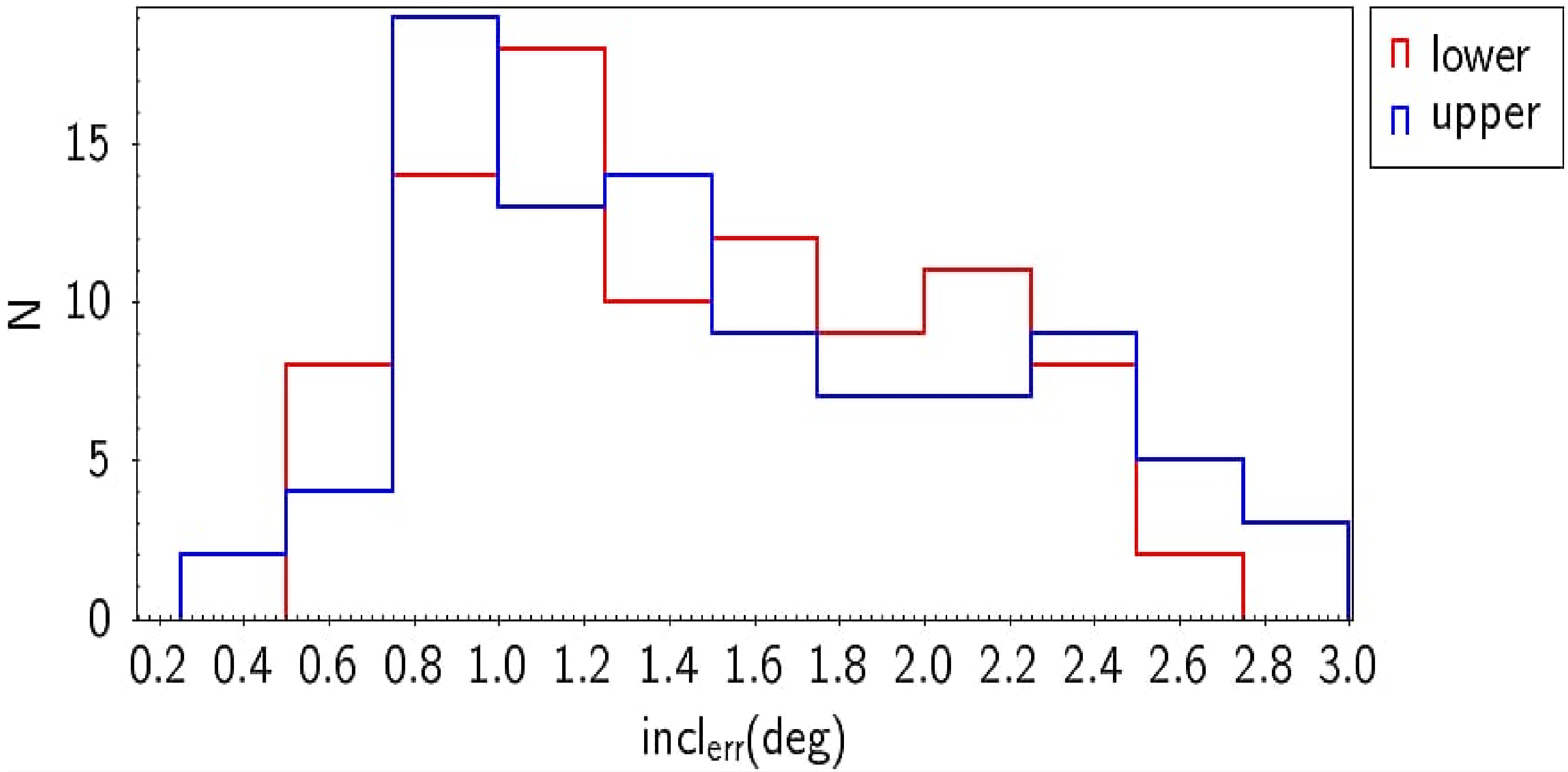




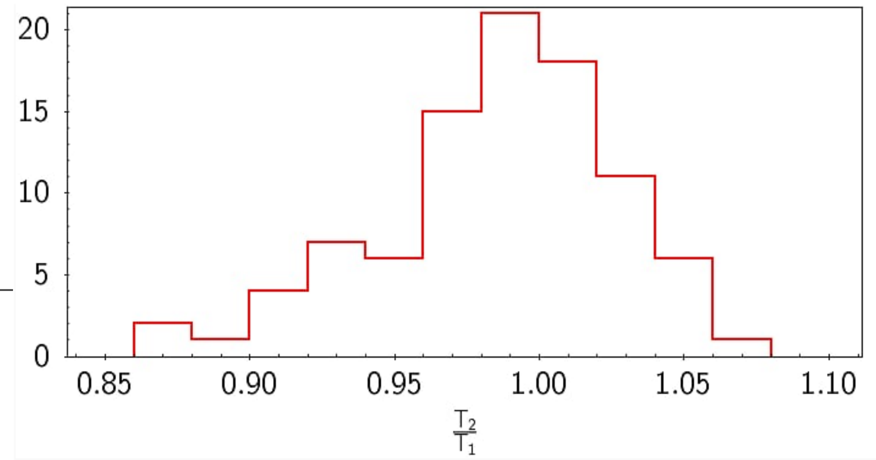




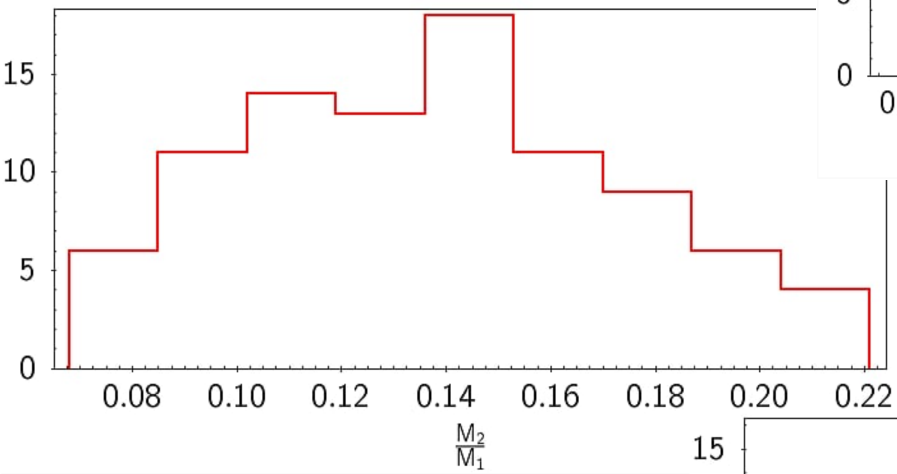
Distribution of $incl_{err}$



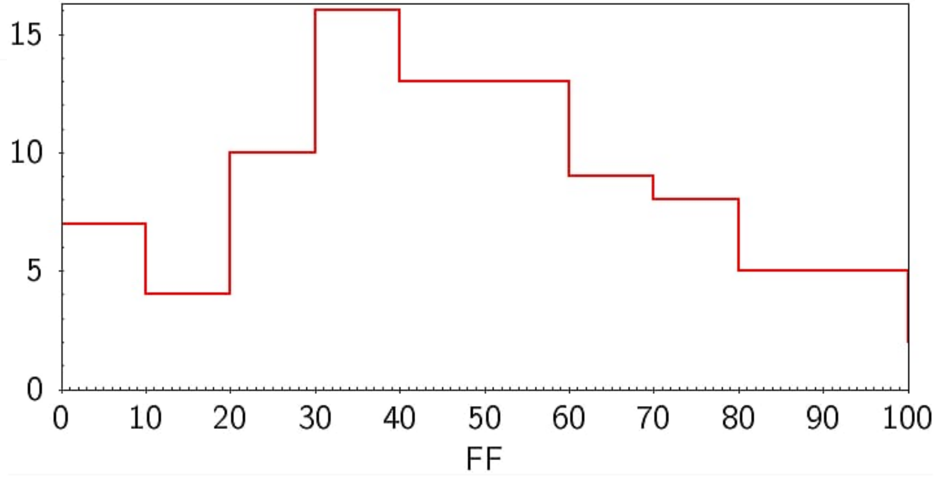
RESULTS



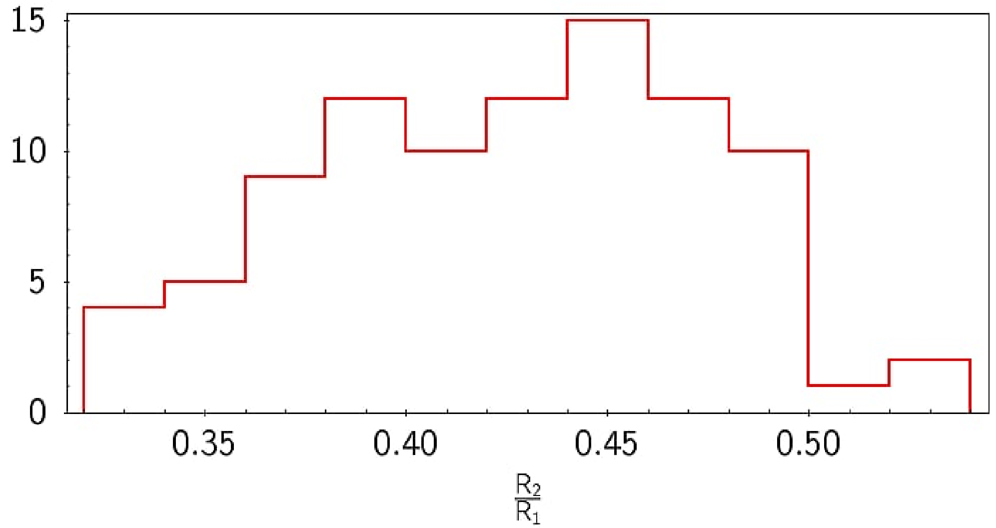
0
5
10
15
20
0.85
0.90
0.95
1.00
1.05
1.10
$\frac{T_2}{T_1}$



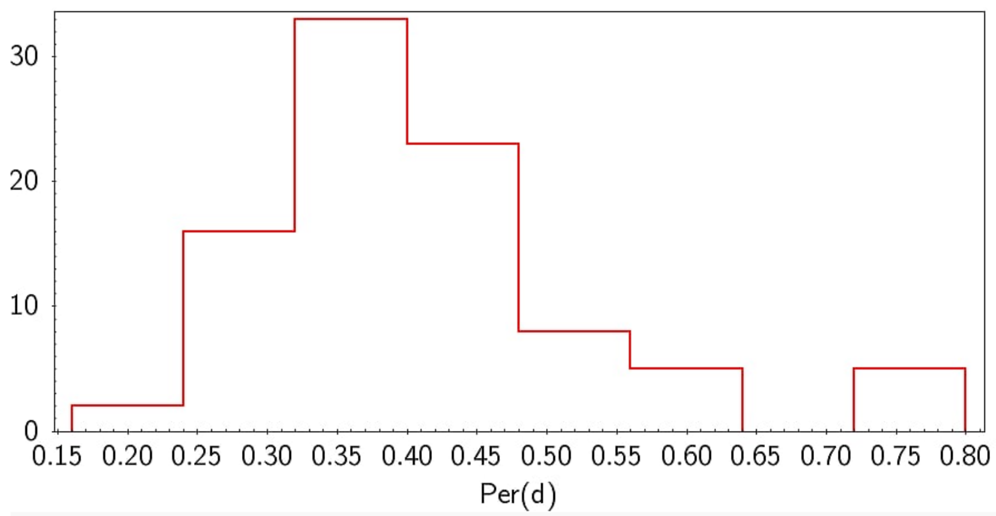
0
5
10
15
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
$\frac{M_2}{M_1}$



0
5
10
15
0
10
20
30
40
50
60
70
80
90
100
FF



15
10
5
0
0.35
0.40
0.45
0.50
$\frac{R_2}{R_1}$



30
20
10
0
0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80
Per(d)

IN THE FUTURE…

- Publish this work
- Period study of these systems
- Search other catalogs (already ASAS)
- Find interesting LMR EWs for photometric & spectroscopic follow up observations

Thank you for your attention