Seeing double or triple with Aristarchos ?
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ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ
UNIVERSITY OF PATRAS

The 12th Hellenic Astronomical Conference

Thessaloniki, June 28 – July 2, 2015

THE PROGRAM

Folllow-up observing program initiated in 2013 with the 2.3 m Aristarchos telescope at Helmos Observatory, Greece,

THE GOAL

Investigate the nature of interesting W UMa type eclipsing binaries from Kepler field

- to verify the Kepler classification
- to construct complete multi-passband light curves
- to determine the spectral type with low resolution spectroscopy
- to model KIC systems using state of the art techniques
- to parameterize the morphology and derive absolute parameters
- to construct O-C diagrams
- to investigate the presence of third body
- to study their evolutionary stage.

Selection of targets

interesting W UMa type eclipsing binaries (EBs) from Kepler field

with periods < 0.45 d and *Kp*(mag) =12.6-16 mag,

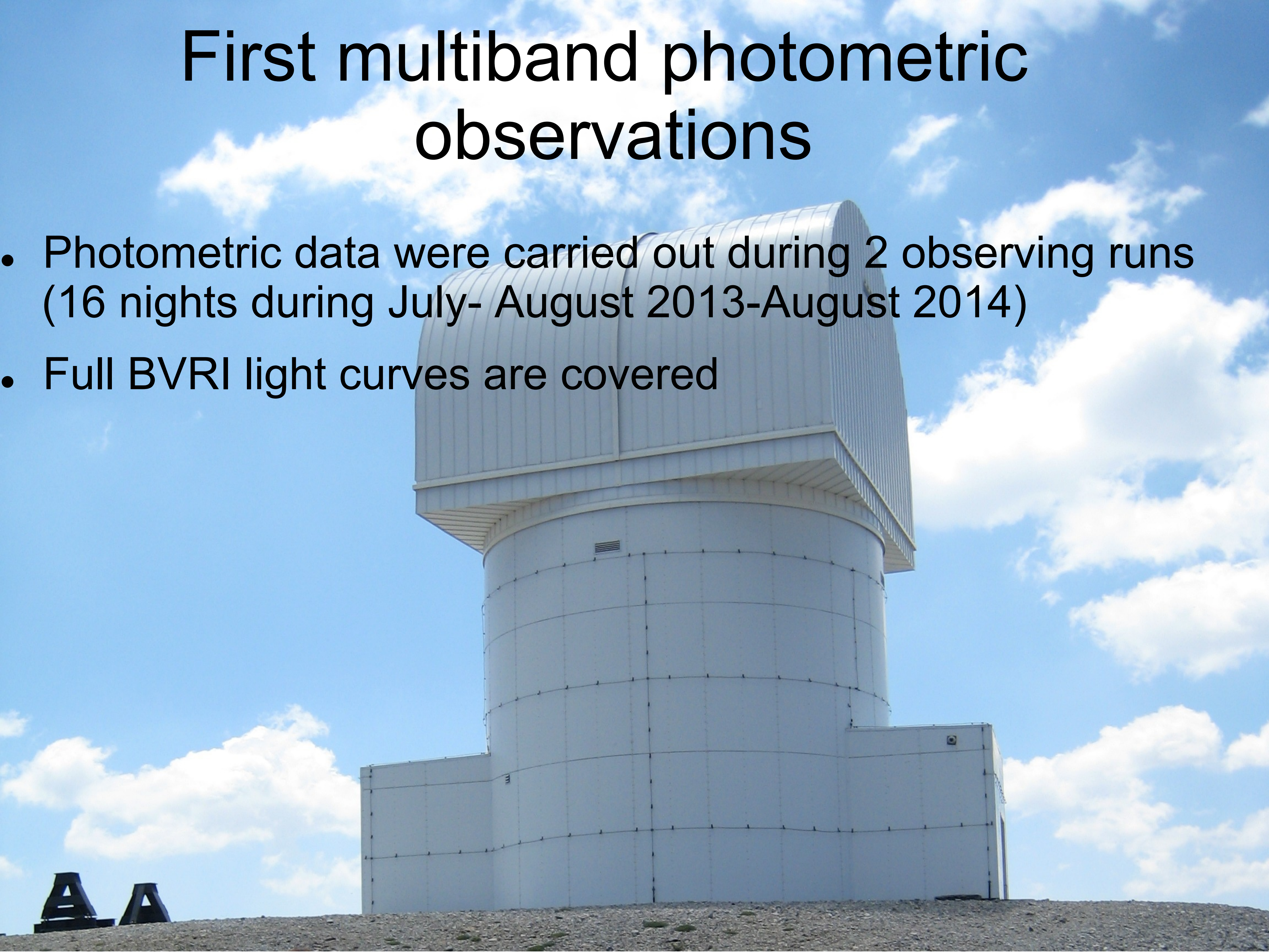
ID	RAJ2000	DecJ2000	Kp mag	Per(d)
KIC07871200	18 50 52.37	+43 40 12.1	12.8	0.242908
KIC4563150	19 28 26.8	+39 39 40.7	13.997	0.274729
KIC11246163	19 31 29.9	+48 59 02.4	14.605	0.279228
KIC8242493	19 39 53.1	+44 10 58.8	14.697	0.283284
KIC8108785	19 42 24.78	+43 55 32.3	14.7	0.228826

- **First estimation of basic parameters are given in *Prsa et al. 2011* based on EBAI analysis**

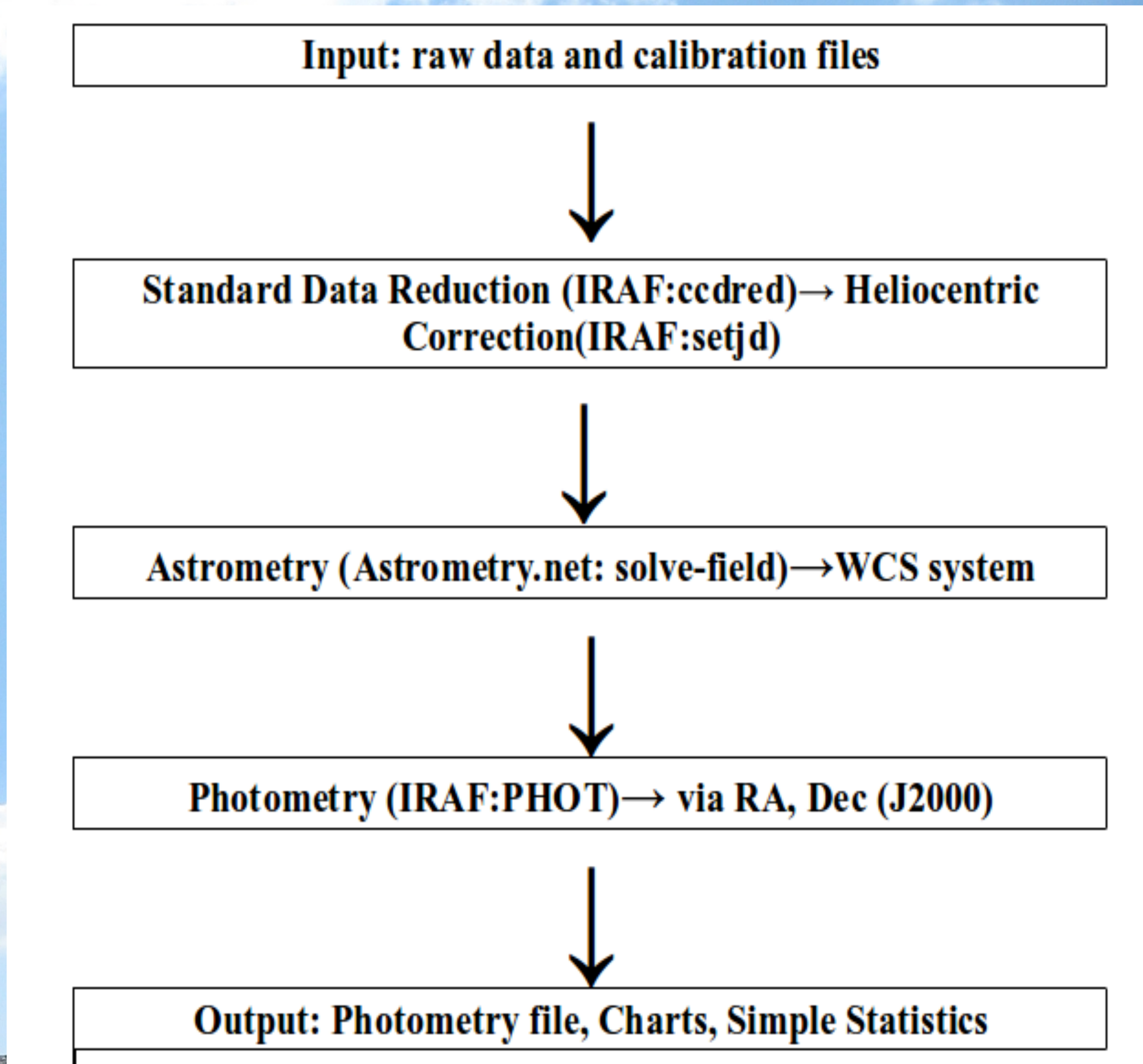
- **Some of the targets have interesting ETV (quadratic, cyclic variations) (*Conroy et al. 2014*) or O'connell effect**

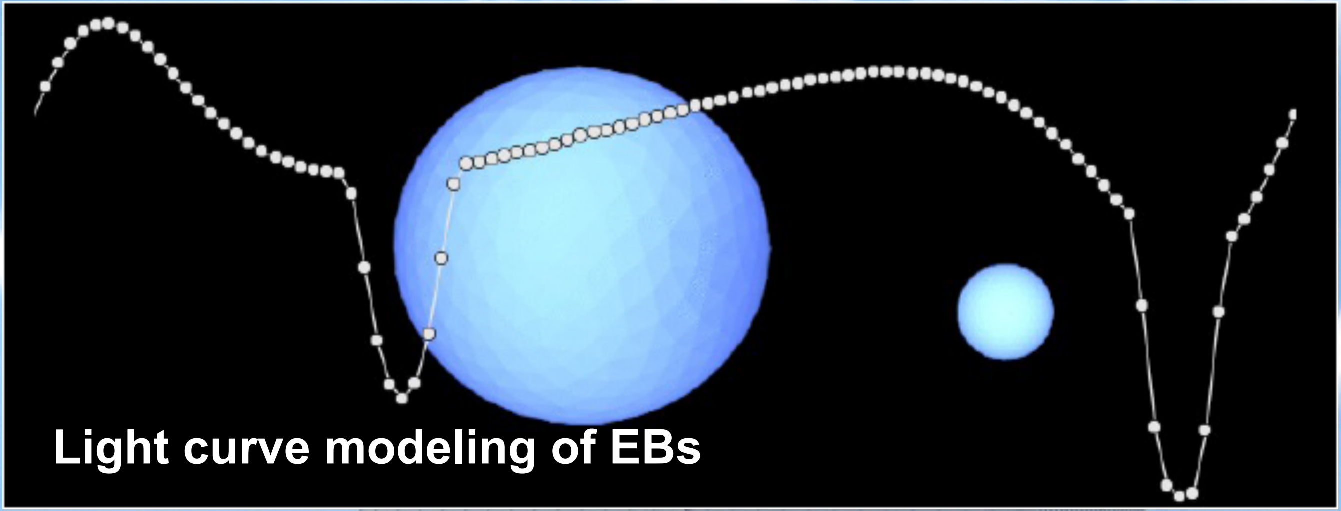
First multiband photometric observations

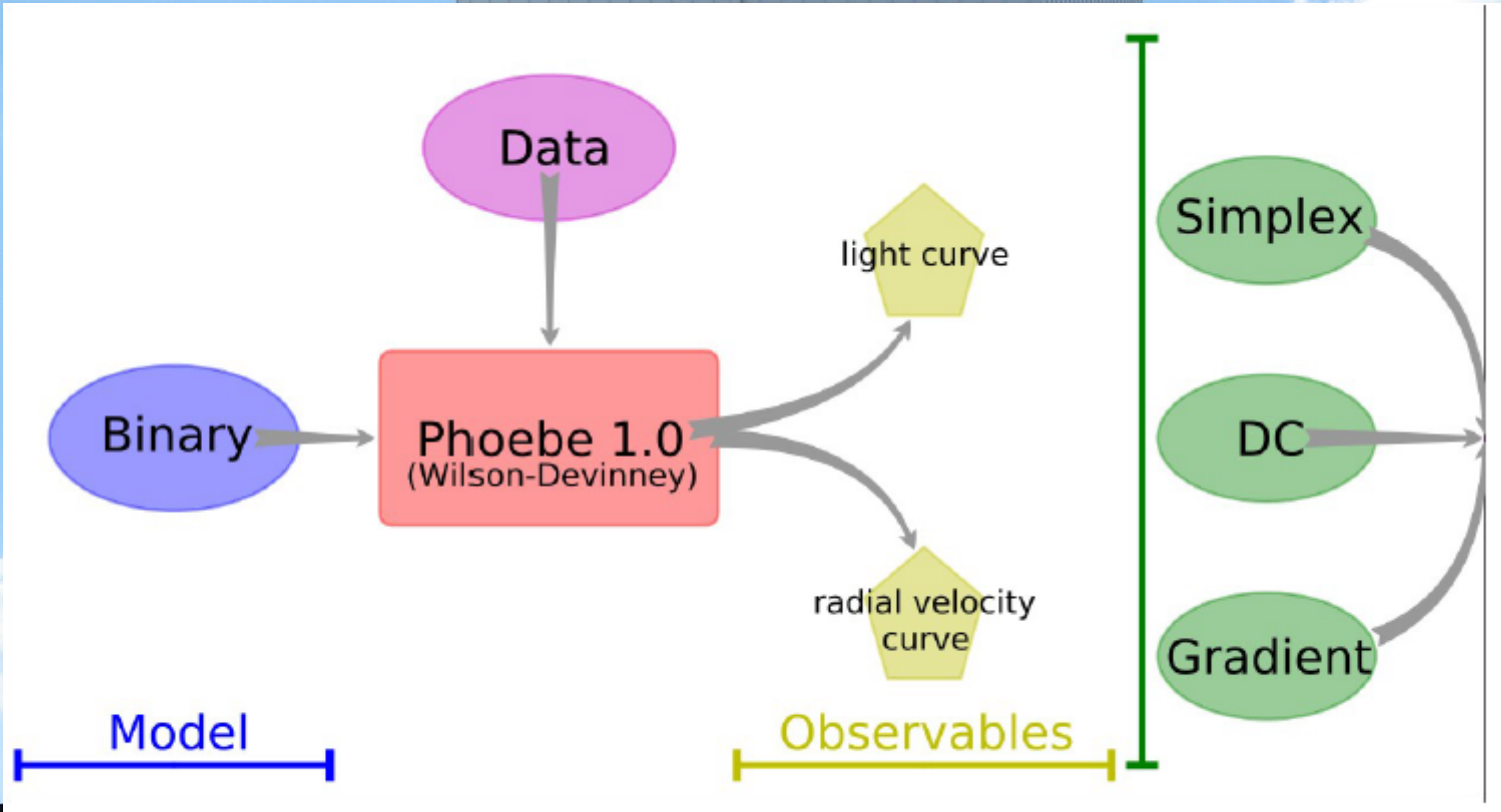
- Photometric data were carried out during 2 observing runs (16 nights during July- August 2013-August 2014)
- Full BVRI light curves are covered



A fully automated pipeline for data reduction and analysis (IRAF, PHOT, Astrometry.net)




Light curve modeling of EBs


Data
light curve
Binary
Phoebe 1.0
(Wilson-Devinney)
radial velocity
curve
Simplex
DC
Gradient
Model
Observables

Light curve modeling of EBs

- Circular orbits
- PHOEBE 1 “Overcontact not in thermal contact"
- The initial models were constructed using q=M2/M1 from EBAI results (Prša et al: 2011, Slawson et al: 2011) and Teff (Huber et al: 2014) These were kept fixed during the fitting procedure
- Fitting with PHOEBE 0.31 scripter in order to conserve *αsini* and/or

  B-V color index, setting multiple subsets (MMS Wilson & Biermann 1976) .

Methods: Searching for global solution and uncertainties

Using **Heuristic Scanning (HS)** with **parameter kicking** to explore the parameter hyperspace (Prsa & Zwitter, 2005) as described in *Christopoulou & Papageorgiou 2015a, Papageorgiou et al, 2015b*

Light curve modeling of EBs

Method 2 : Genetic Algorithm-based numerical optimization technique inspired from the biological process of evolution by means of **natural selection (Metcalfe 1999, 2000)**

-Setting parameter ranges

-Creating randomly set of models according to their limits (“population”)

1) Calculate CFV from the model (PHOEBE-script) (“fitness”)
2) Accept the best set of parameters from the list according to minimum CFV and propagate to next generation.
3) Select the pairs of solutions according to their fitting (“parents”)
4) Apply crossover and mutation (“offspring”)
5) Check if the models are physically feasible and propagate to next generation
6) Go to 1

-Evolve the initial list and create generations

Methods: Modeling the light curves(cont.)

$X_1\ Y_1$, $X_2\ Y_2$ are the parameters derived from S_1 and S_2 solutions

Step1:Crossover

encoding the parameters as a string-like structure "chromosome")

X_1=4.8563 Y_1= 8.2543 → 4856382543 genome 1
→4856482543→ 4856|482543 → 4856|189264→4856189264→
newgenome1

Same colour build a new Genome with information from both parents (initial values of parameters). The position to cut is random

X_2=4.6791 Y_2= 8.9264→4679189264 genome 2
→4679189264→ 4679|189264→4679|482543→4679482543
→ newgenome2

Apply mutation to new genomes 1& 2 and reconstruction.

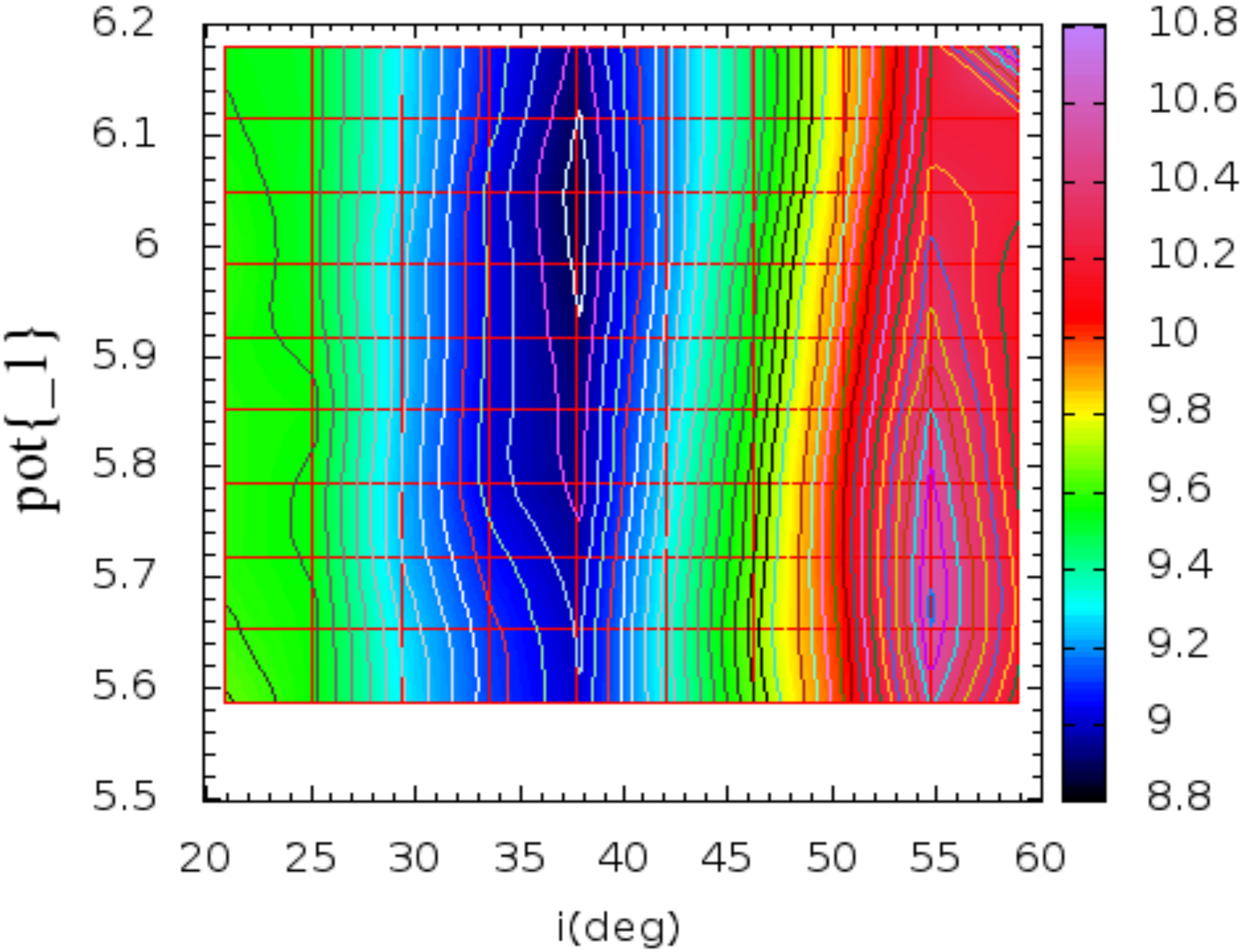
Step2: Mutation

newgenome1→mutation→48561892|64→485618|0264
→X_1'=4.8561 Y_1'=8.9204
newgenome2→mutation→46794825|43→ 467948|0543
→ X_2'=4.6794 Y_2'=8.2503

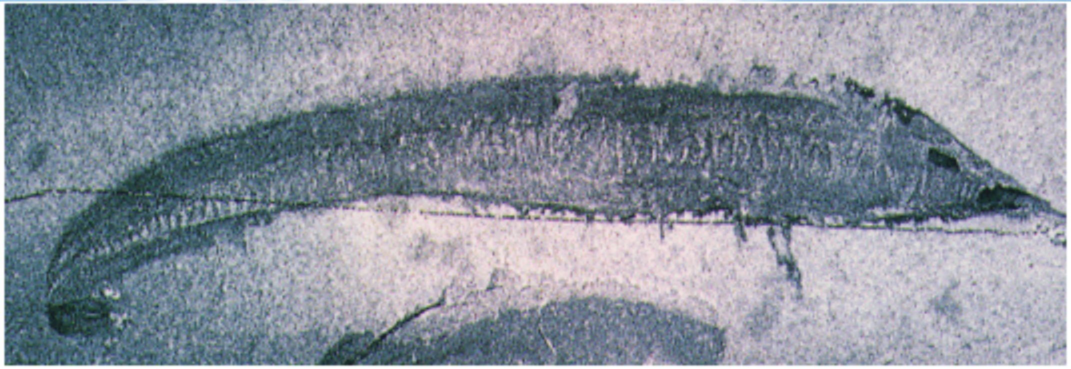
New parameter values:

X_1=4.8563 Y_1= 8.2543 →X_1'=4.8561 Y_1'=8.0204
X_2=4.6791 Y_2= 8.9264 →X_2'=4.6794 Y_2'=8.0503

Methods: Modeling the light curves(cont.)



Methods: Modeling the light curves(cont.)



***Pikaia Gracilens**, a little worm-like beast that crawled in the mud of a long gone seafloor of the Cambrian era, 530 million years ago. While not particularly impressive in the tooth and claw department, Pikaia is believed to be the founder of the phylum Chordata, whose subsequent evolution had consequences still very much felt today by the rest of the ecosystem. Image digitized from the excellent book The Rise of Fishes, by John A. Long (1995, The Johns Hopkins University Press)*

PIKAIA (public domain software High Altitude Observatory) to solve whatever global optimization problem (Driver program written by Papageorgiou)

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Preliminary Solutions for KIC4563150 & KIC11246163

- The systems are third body candidates (*Conroy et al. 2014*)

The EBAI project (Prša et al: 2011, Slawson et al: 2011) using artificial neural netwoks and Kepler's mission light curves, determined *a first approach* of their fundamental parameters (q, T_2/T_1, f and i).

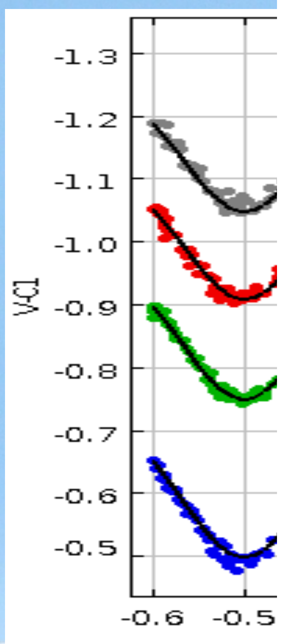
The initial models were constructed using the mass ratio $q=M_2/M_1$ from EBAI results and the updated effective temperature of the systems from *Huber et al: (2014)* for the more massive component. These were kept fixed during the fitting procedure.

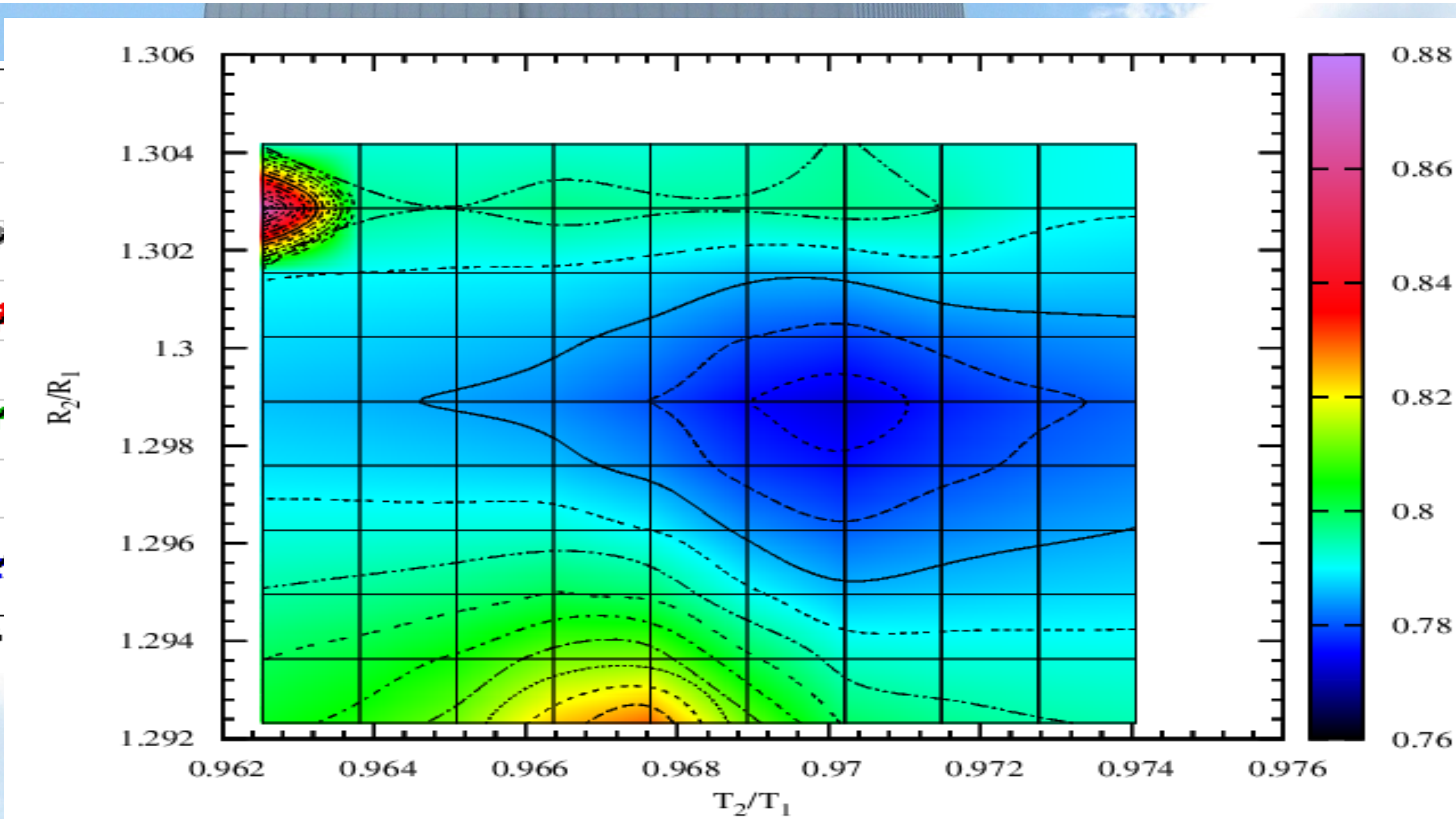
Results(KIC4563150)

EBAI overcontact eclipsing binary system.
q=1.77, i°=67   f(%)=51, T_{eff} (K)=4998±143 *(Huber et al: 2014)*
Third body candidate (*Conroy et al. 2014*)

Observations

948 images B (240) V (238) R (238) I (232). 8 Minima (4 primary,4 secondary).   New ephemeris, same period

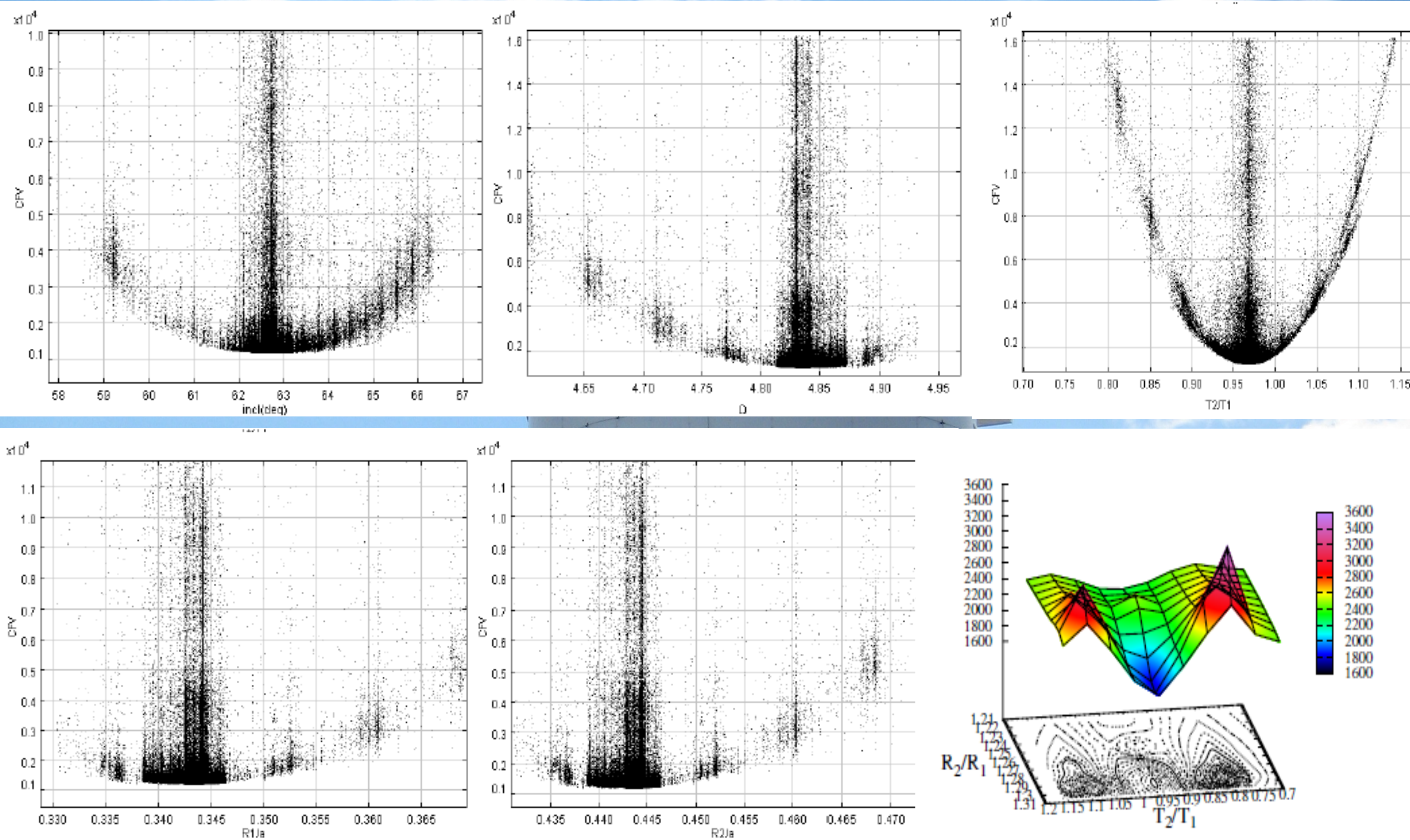




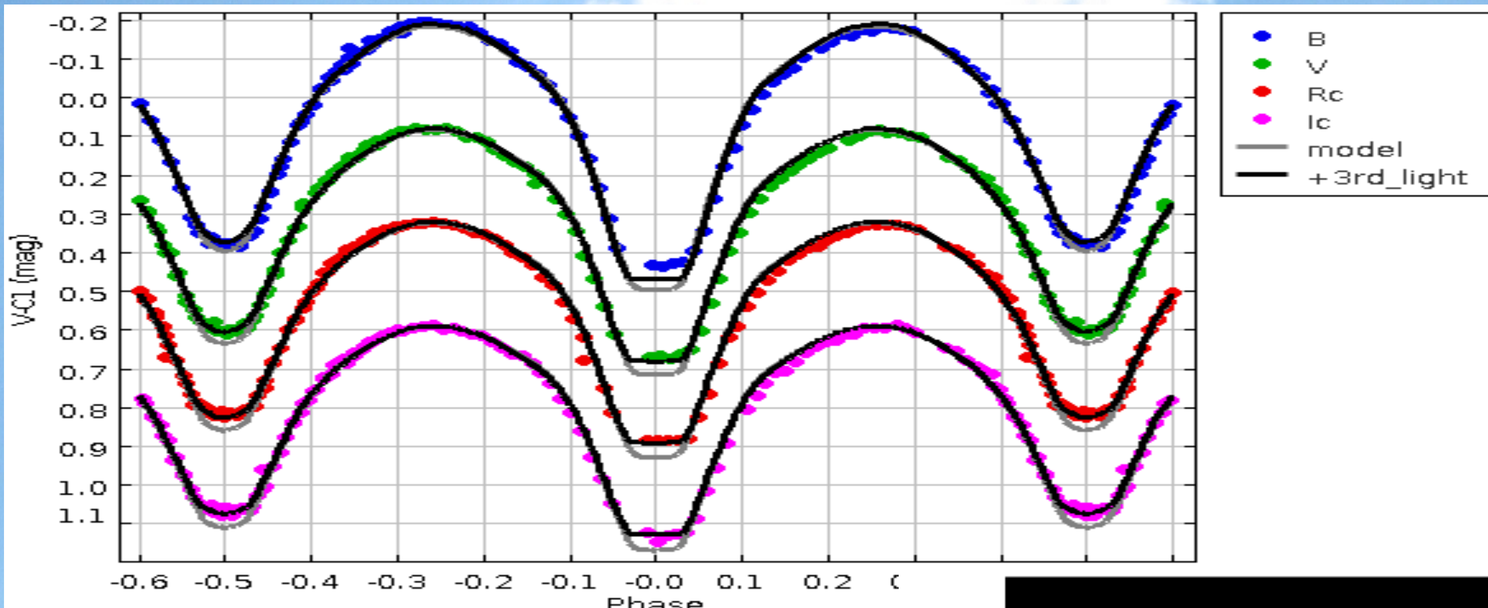
PIKAIA + PHOEBE scripter

T_1, T_2, [4200K- 6500K], Ω [4.34 – 4.93] i[45- 80], L_3 [0-15%]

Initial population of 120 solutions evolved to 1000 generations



Results(KIC11246163)



Observations

471 images

B (112) V (120) R (120) I (119).

8 Minima II

New ephemeris, same period

EBAI overcontact

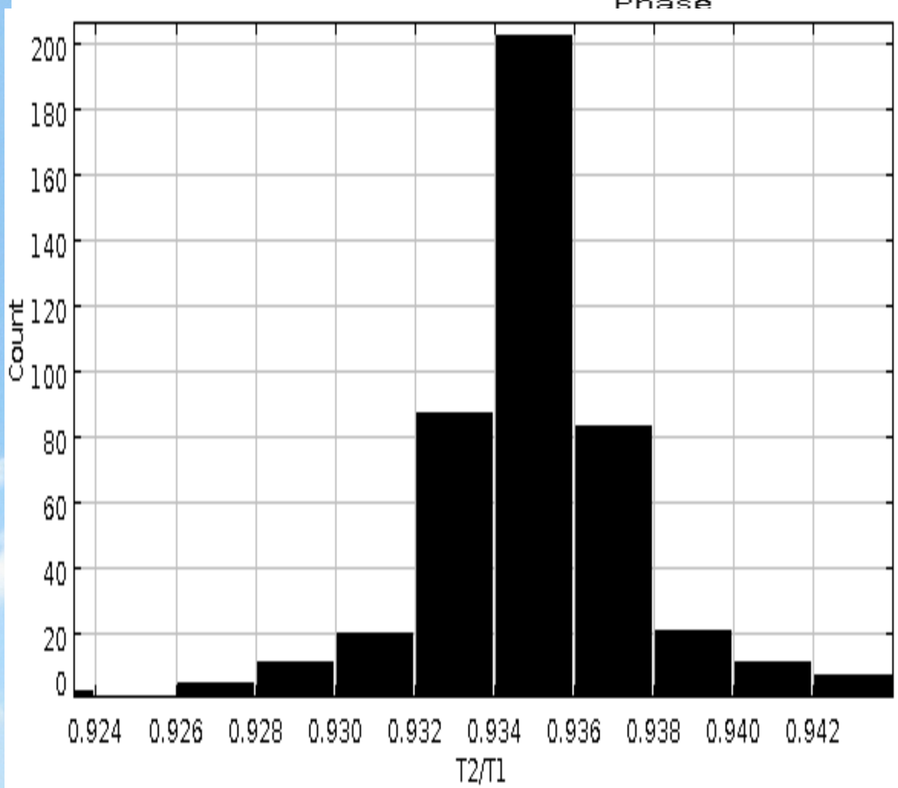
eclipsing binary system

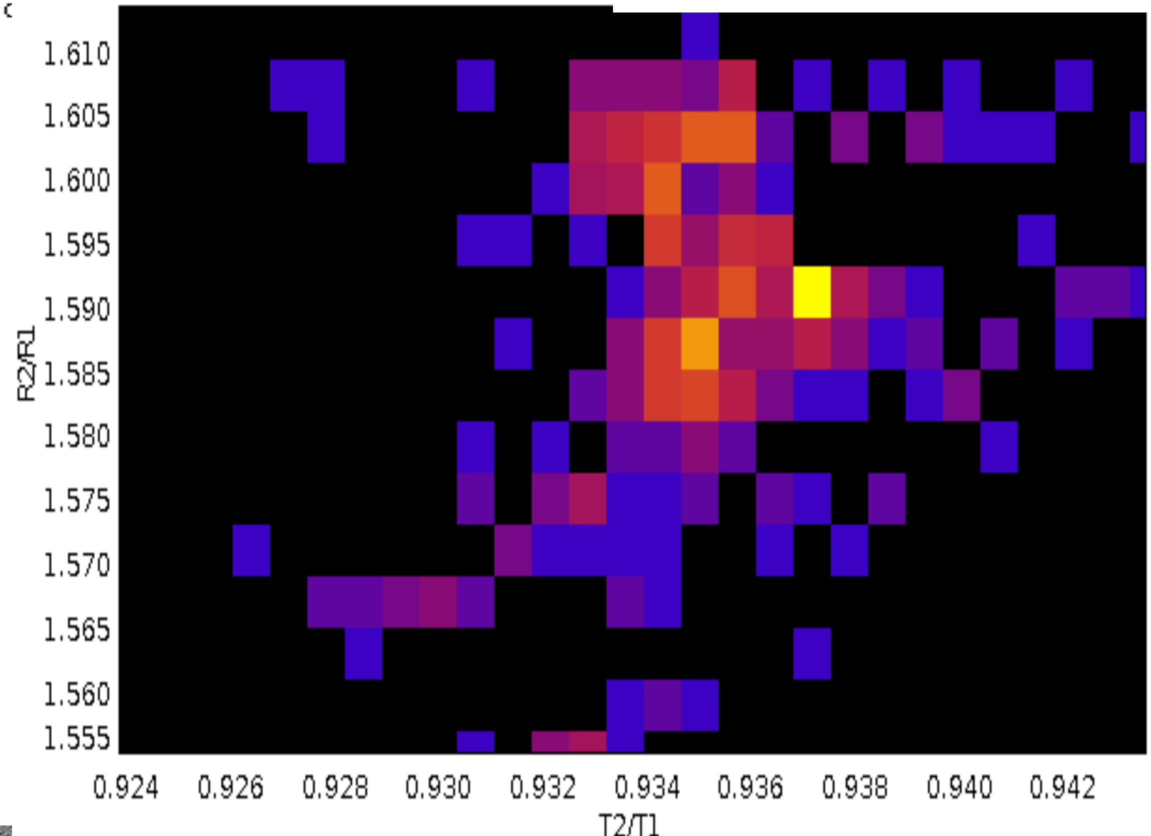
q=1.75, i^{o}=81,

f(%)=23

T_{eff} K)=5545±175

(Huber et al: 2014)

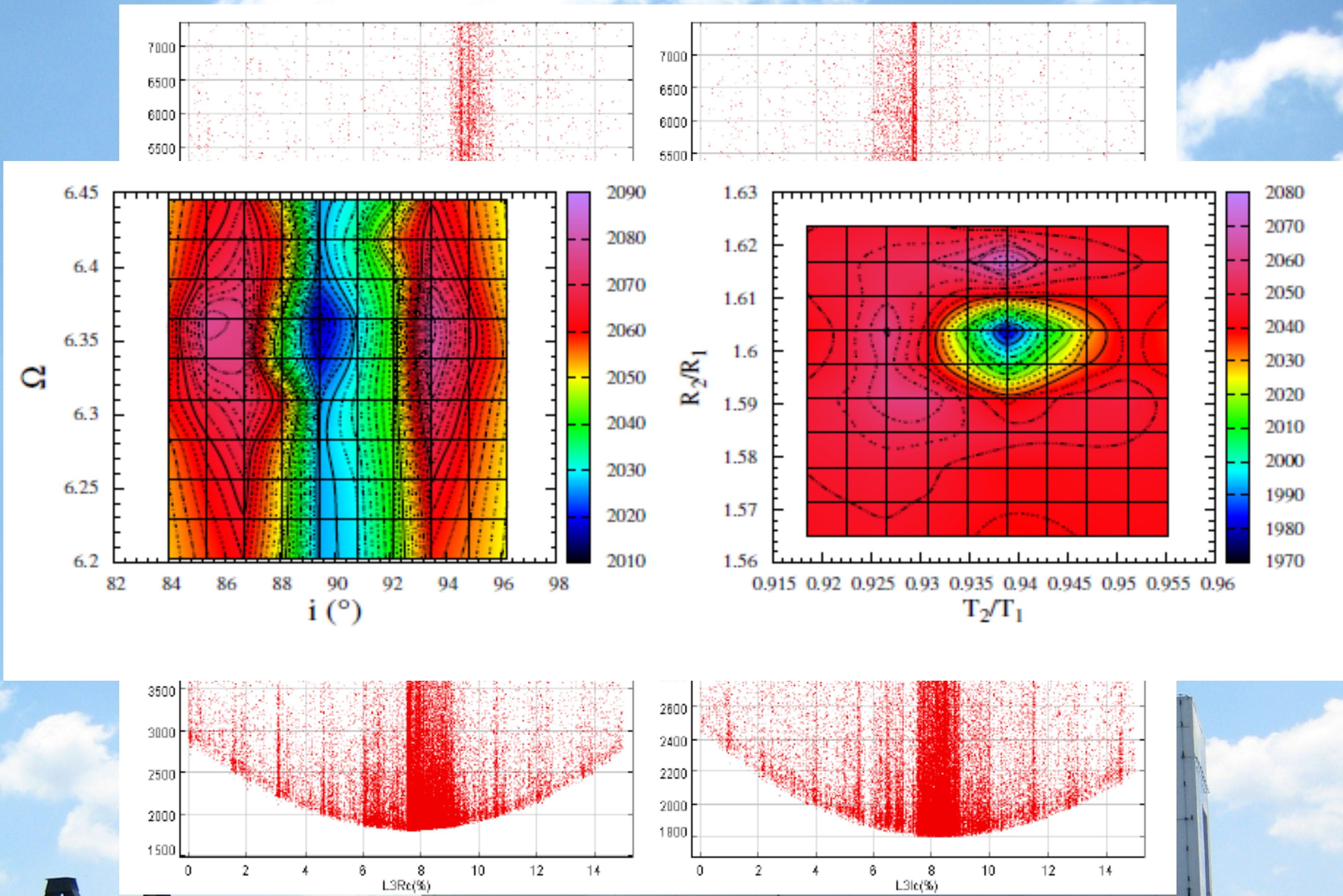




PIKAIA + PHOEBE scripter

T_1,T_2, [4500K- 6500K], Ω [5.86 – 6.48] i [70- 100], L_3 [0-15%]

Initial population of 120 solutions evolved to 1000 generations



Παράμετρος	KIC4563150	KIC11246163
HJD_0	2456517.48816(20)	2456519.579624(10)
Period(days)	0.274729(1)	0.279228(1)
$i(^o)$	62.5(1.0)	89(1.4)
$q=M_2/M_1$	1.77	2.9(1)
T_2/T_1	0.97(1.5)	0.94(2)
R_2/R_1	1.29(1)	1.59(1)
$\Omega_1=\Omega_2$	4.84(5)	6.31(5)
L_{1B}/L_{Btot}	0.429(4)	0.336(4)
L_{1V}/L_{Vtot}	0.415(3)	0.319(4)
L_{1Rc}/L_{Rctot}	0.407(3)	0.305(4)
L_{1Ic}/L_{Ictot}	0.400(2)	0.300(4)
L_{2B}/L_{Btot}	0.571(4)	0.594(6)
L_{2V}/L_{Vtot}	0.585(3)	0.601(6)
L_{2Rc}/L_{Rctot}	0.593(3)	0.606(6)
L_{2Ic}/L_{Ictot}	0.600(3)	0.609(7)
L_{3B}/L_{Btot}		0.070(8)
L_{3V}/L_{Vtot}		0.080(8)
L_{3Rc}/L_{Rctot}		0.089(8)
L_{3Ic}/L_{Ictot}		0.091 (8)

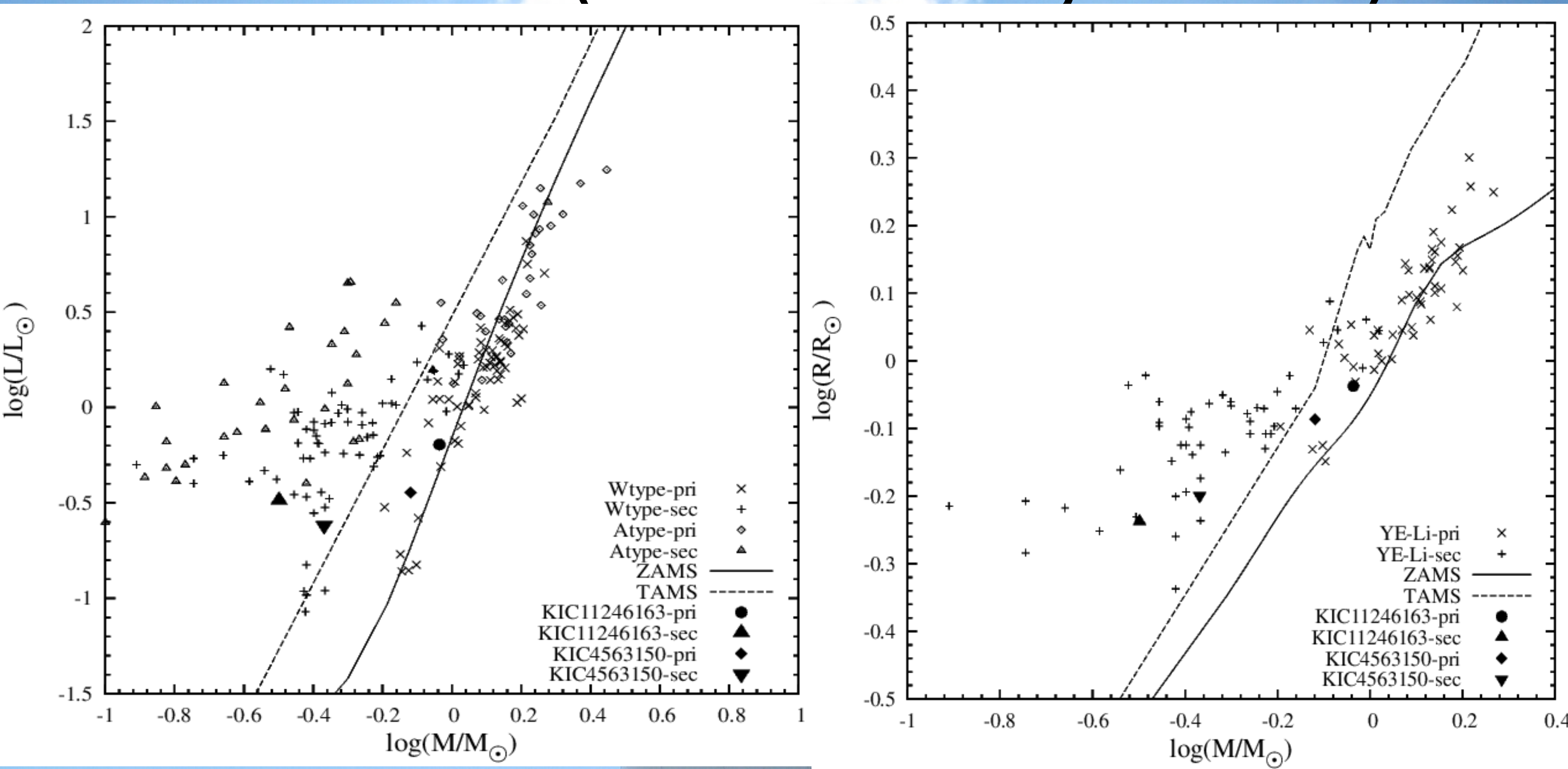
Conroy et al : 2014

Preliminary Physical Parameters

Parameter	KIC4563150	KIC11246163
$T_h(K)$	5092(143)	5786(138)
$T_2(K)$	4939(143)	5439(138)
$R_h(R_\odot)$	0.63(0.09)	0.56(0.04)
$R_c(R_\odot)$	0.82(0.09)	0.89(0.04)
$M_h(R_\odot)$	0.42(0.10)	0.30(0.10)
$M_c(R_\odot)$	0.76(0.10)	0.87(0.10)

W subtype W UMa

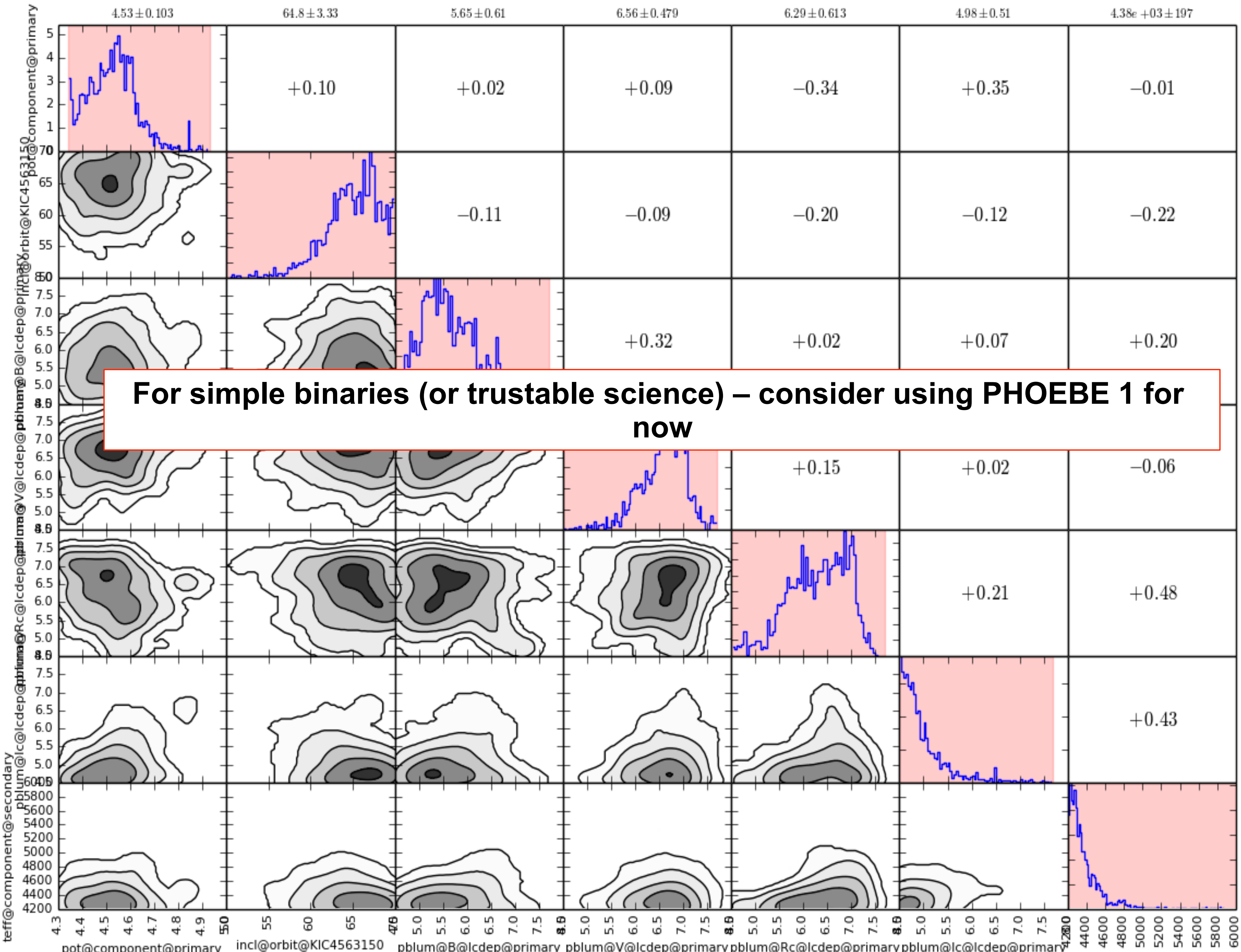
Results(Evolutionary status)



Check the evolutionary status, producing the *LogM-LogL, LogM-LogR*, with ZAMS and TAMS from BSE code *(Hurley et al. 2002)*

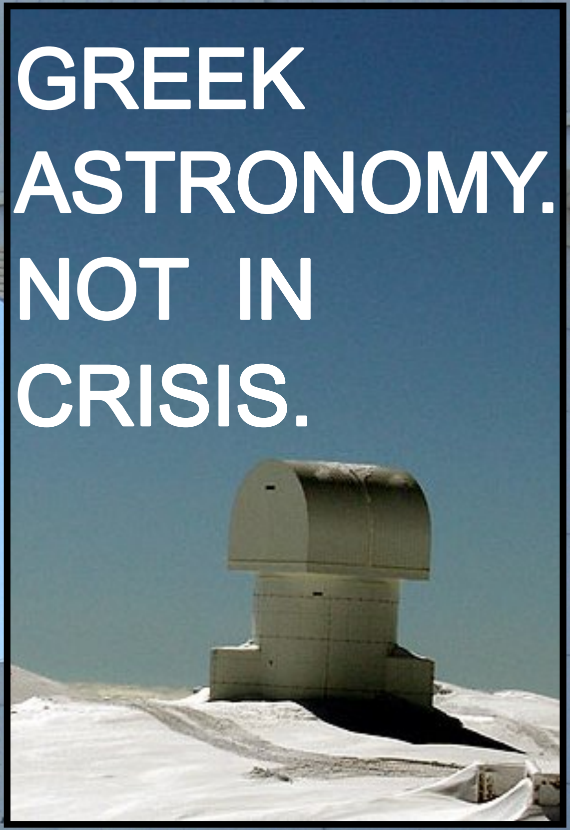
Future Work

- Spectroscopic observations q, asini, V, 3^{d} body
- Fitting using PHOEBE 2.0 (pymc, emcee,lmfit routines etc.)



For simple binaries (or trustable science) – consider using PHOEBE 1 for now

Thank you for your attention



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Decide
Yes
No