Does the microlensing event OGLE-2013-BLG-446 contain a rocky planet?

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Summary

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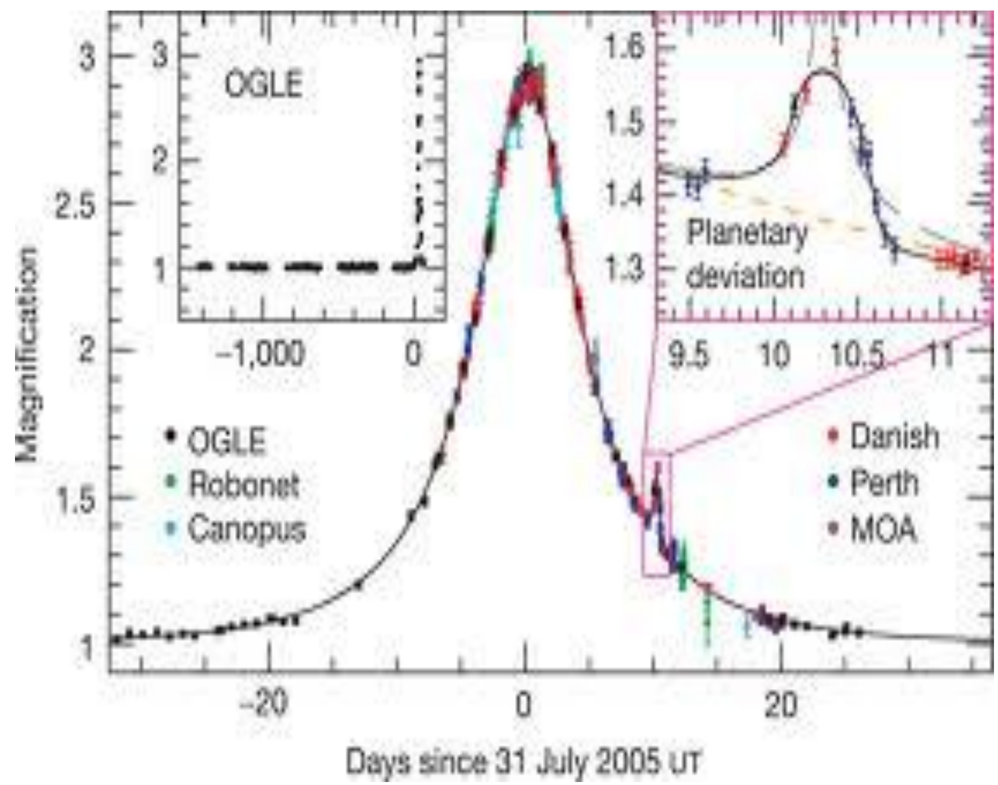
I. Introduction

Microlensing is sensitive down to Earth mass planet (under conditions)

But….

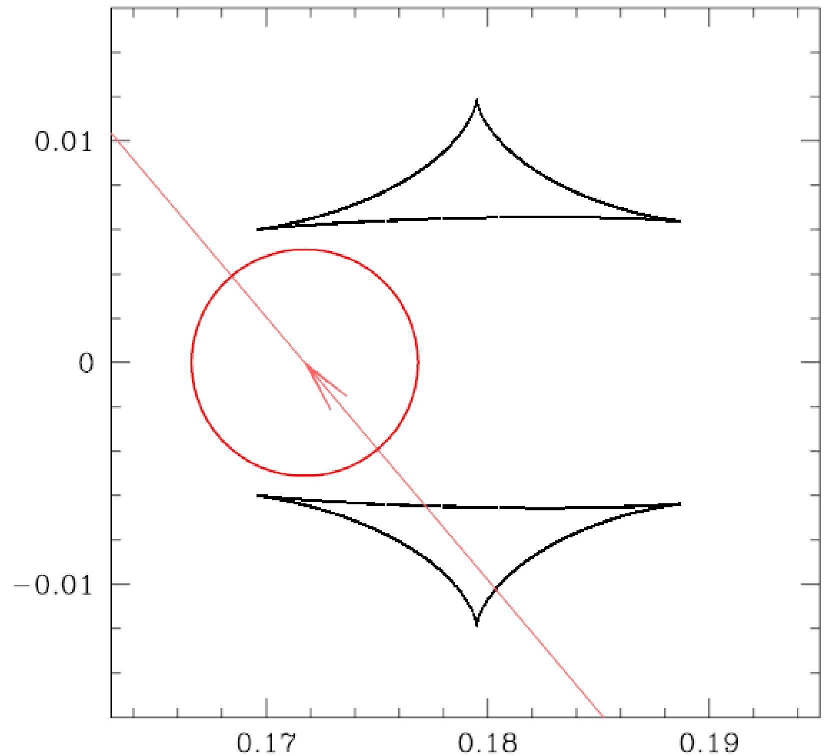


Beaulieu et al. (2006)

You need to be lucky !

Two cases :

1) Approach the planetary caustic

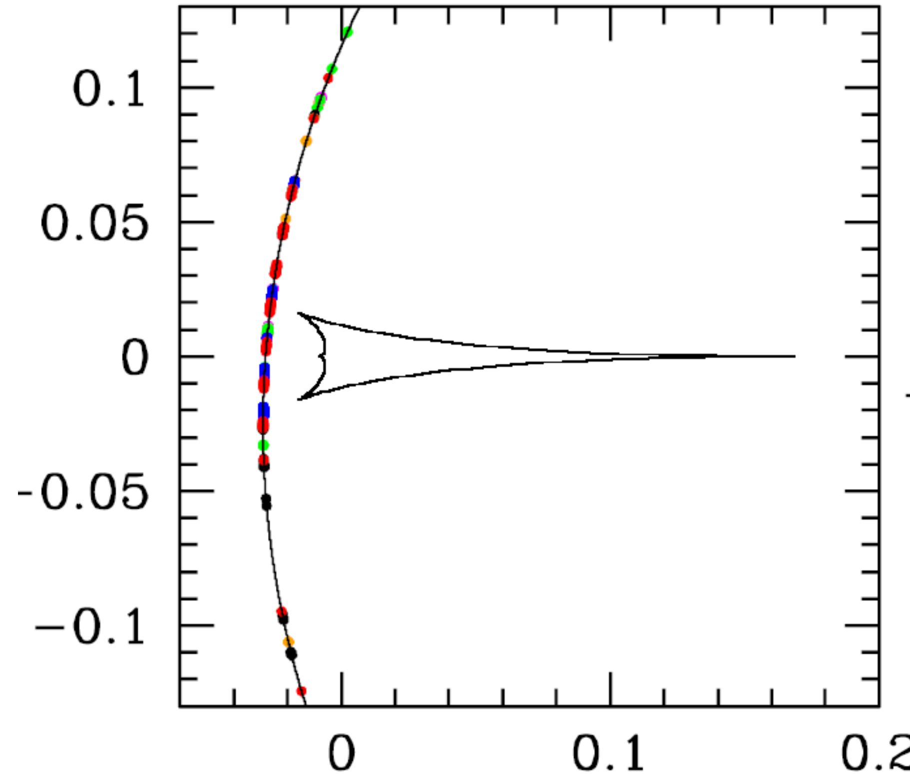


Muraki et al. (2011)

Low-magnification events (Amax<50,Uo>0.02)

You need to be lucky !

2) Approach the central caustic



Dong et al. (2009)

High-magnification events (Amax>50,Uo<0.02)

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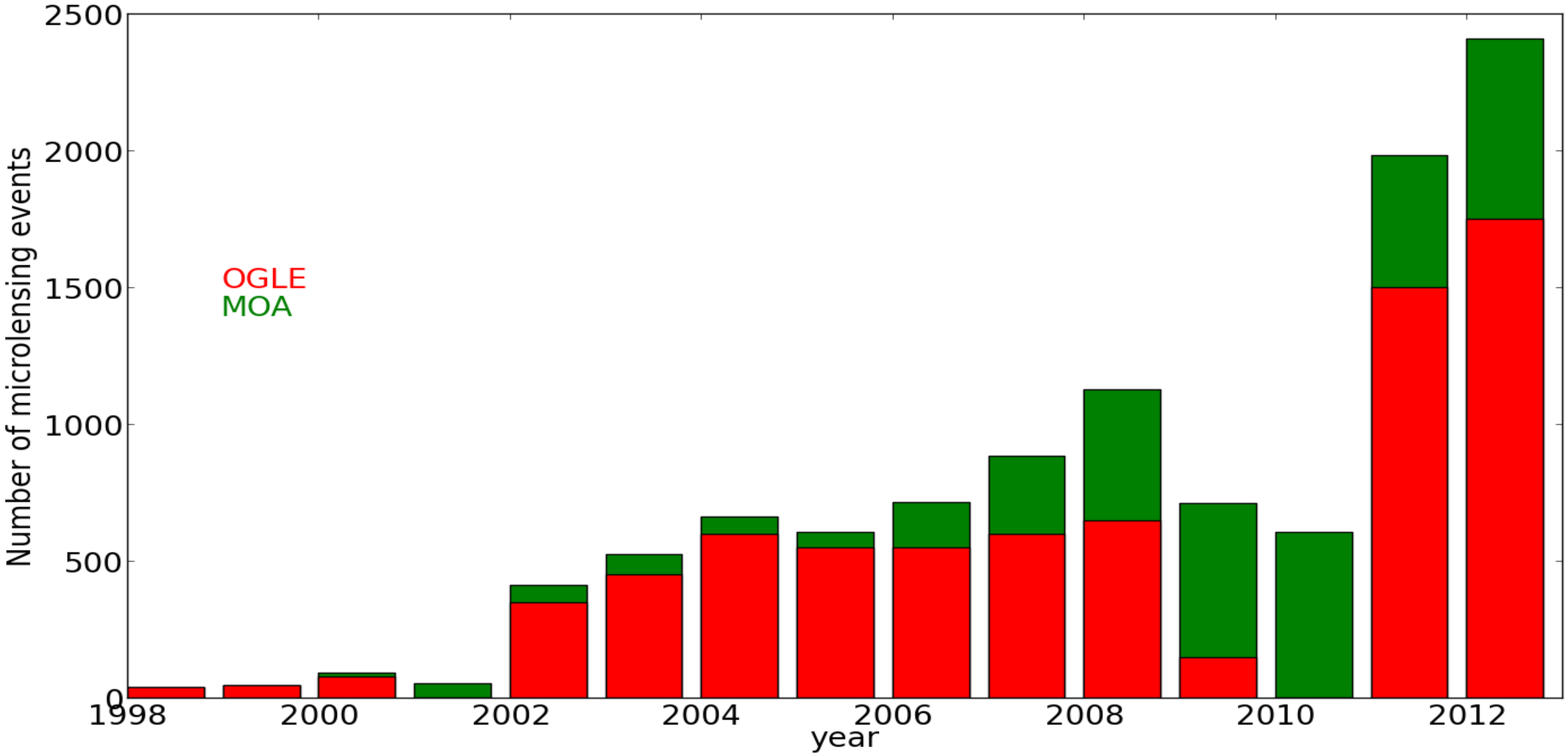


Change of the follow-up teams strategy around 2010

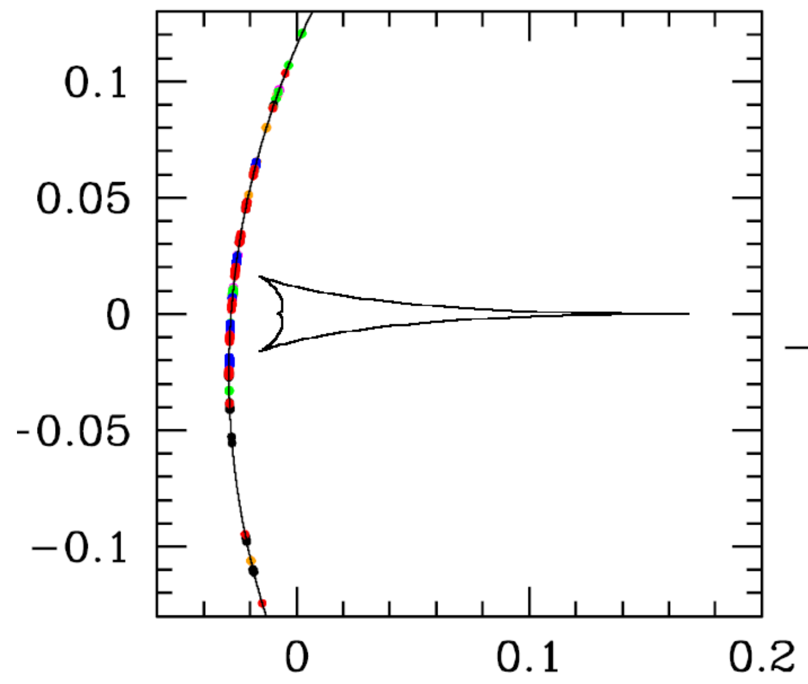
↓

focus on high magnification events

However, central caustic deviations can be hard to catch.

Caustic width : $\omega \sim q$

Dong et al. (2009)



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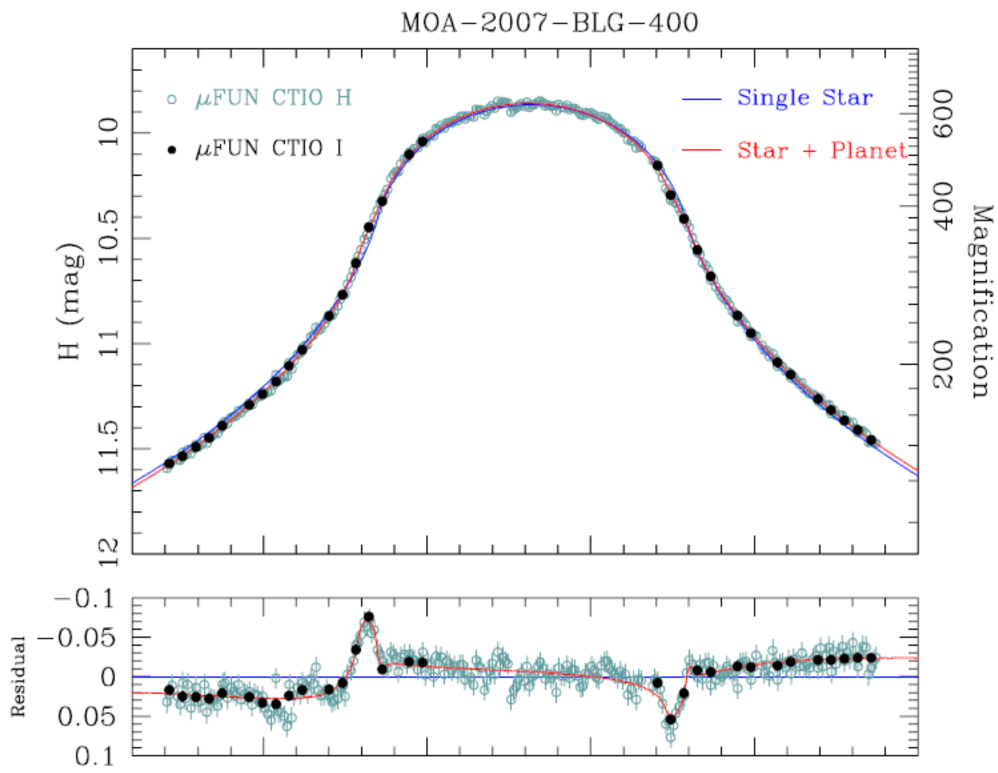
Finite source effects can greatly decrease the signal!

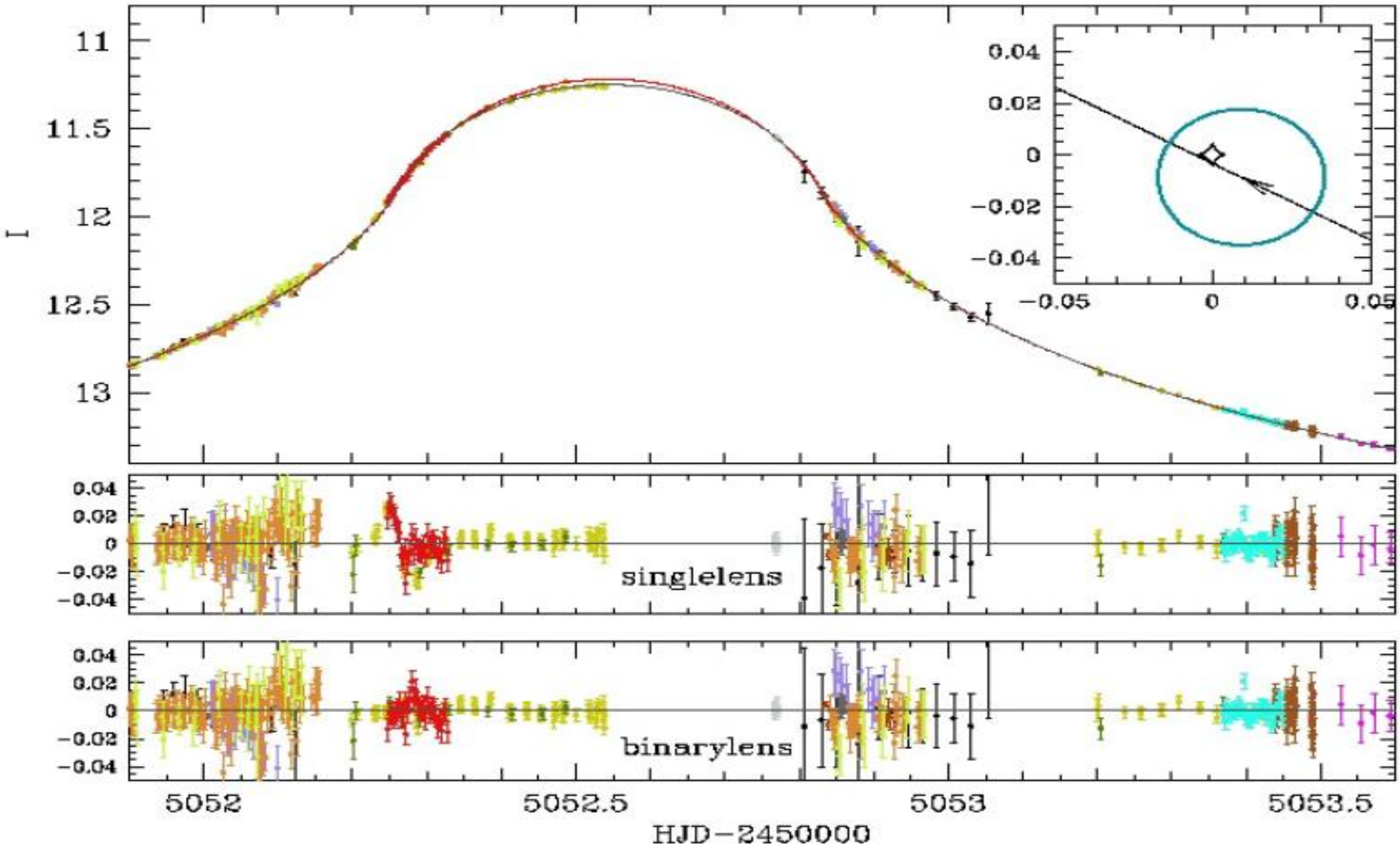
Occurs for ω/ρ<2

Dong et al. (2009)



ω/ρ ~ 0.4

Finite source effects can greatly decrease the signal!



Bachelet et al. (2012)

$\omega/\rho \sim 0.3$

II. OGLE-2013-BLG-446

High magnification event : Amax $\sim$ 3000

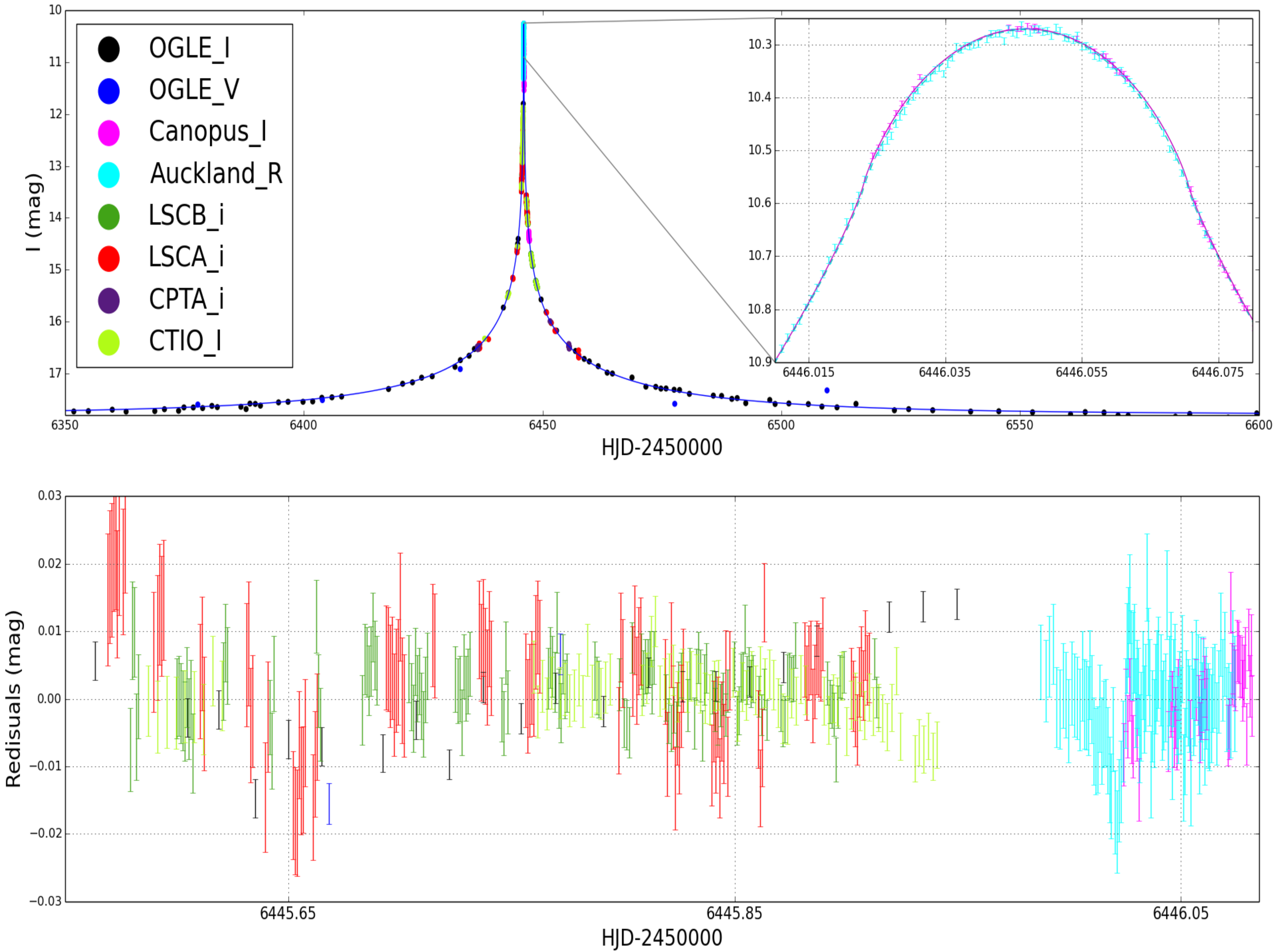
↳ potential terrestrial parallax measurement

Long Einstein ring crossing time $t_E \sim$ 80 days

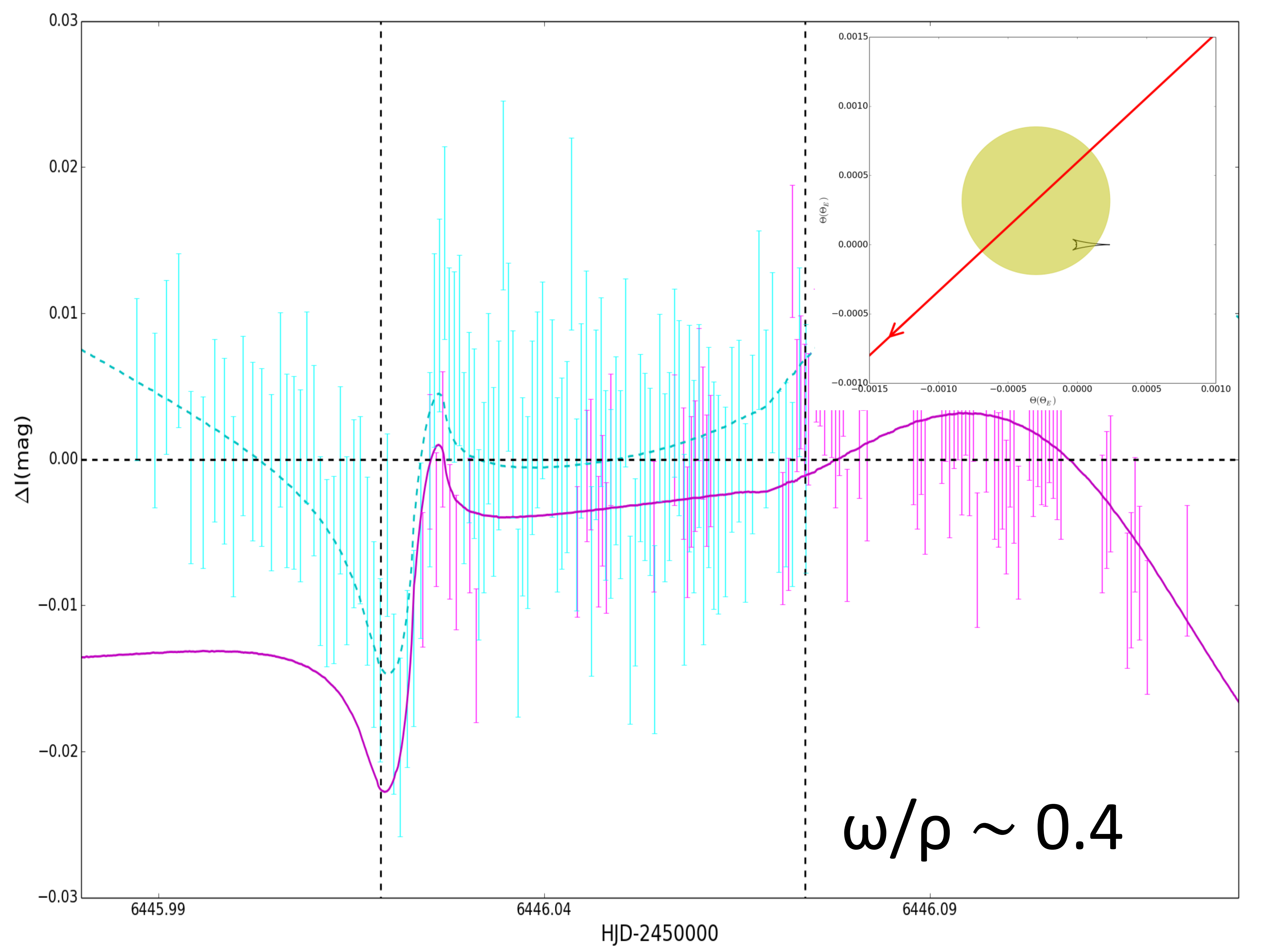
↳ potential annual parallax measurement

Finite source effects : $\rho \sim 5\ 10^{-4}$

Nice follow-up covergage



OGLE_I
OGLE_V
Canopus_I
Auckland_R
LSCB_i
LSCA_i
CPTA_i
CTIO_I
I (mag)
10
11
12
13
14
15
16
17
10.3
10.4
10.5
10.6
10.7
10.8
10.9
6446.015
6446.035
6446.055
6446.075
6350
6400
6450
6500
6550
6600
HJD-2450000
Redisuals (mag)
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
6445.65
6445.85
6446.05
HJD-2450000



ΔI(mag)
HJD-2450000
6445.99
6446.04
6446.09
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
Θ(Θ_E)
ω/ρ ~ 0.4

Parameters	FSPL	FSPL+Annual parallax	FSPL+Terrestrial parallax	Close planetary (FSBL)
t_o(HJD)	$6446.04680 \pm 1.5\ 10^{-5}$	$6446.04679 \pm 3.4\ 10^{-5}$	$6446.04698 \pm 1.8\ 10^{-5}$	$6446.04663 \pm 3.2\ 10^{-5}$
$U_o(\theta_E)$	$-4.14\ 10^{-4} \pm 6.1\ 10^{-6}$	$-4.03\ 10^{-4} \pm 9.8\ 10^{-6}$	$-4.08\ 10^{-4} \pm 6.9\ 10^{-6}$	$-4.35\ 10^{-4} \pm 5.1\ 10^{-6}$
t_E(days)	77.2 ± 1.1	79.4 ± 1.9	77.2 ± 1.2	75.3 ± 0.8
$\rho(\theta_E)$	$5.17\ 10^{-4} \pm 7.5\ 10^{-6}$	$5.02\ 10^{-4} \pm 1.2\ 10^{-5}$	$5.12\ 10^{-4} \pm 8.5\ 10^{-6}$	$5.35\ 10^{-4} \pm 6.0\ 10^{-6}$
I_s(mag)	19.01 ± 0.02	19.04 ± 0.03	19.01 ± 0.02	18.98 ± 0.01
V_s(mag)	20.50 ± 0.02	20.53 ± 0.03	20.50 ± 0.02	20.47 ± 0.01
I_b(mag)	18.21 ± 0.01	18.19 ± 0.01	18.21 ± 0.01	18.23 ± 0.01
V_b(mag)	22.42 ± 0.07	22.26 ± 0.12	22.41 ± 0.08	22.60 ± 0.07
Π_{EN}		-0.33 ± 0.23	0.14 ± 0.02	
Π_{EE}		0.22 ± 0.08	0.15 ± 0.02	
$s(\theta_E)$				0.775 ± 0.048
q				$1.608\ 10^{-5} \pm 3.415\ 10^{-6}$
α(rad)				-2.39 ± 0.02
χ^2	4279.289	4187.788	4182.173	4001.298

III. Study of photometric systematic errors

General problem of exoplanets surveys

Systematic errors can be same level as the signal

Several physical process can generate systematic erros

Physical cause	Related quantity
CCD non linearities	Exposure time
Varying extinction	Airmass
Varying seeing disk	PSF FWHM
Reduction quality	Photometric scale factor Background
Extinction and transparancy	Time
Flat-fields error	Detector coordinates

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Model

$$m = M + Z$$

↓ Differentiating the χ^2

$$\begin{pmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{B}^{\mathrm{T}} & \mathbf{D} \end{pmatrix} \begin{pmatrix} \boldsymbol{x}_1 \\ \boldsymbol{x}_2 \end{pmatrix} = \begin{pmatrix} \boldsymbol{v}_1 \\ \boldsymbol{v}_2 \end{pmatrix}$$

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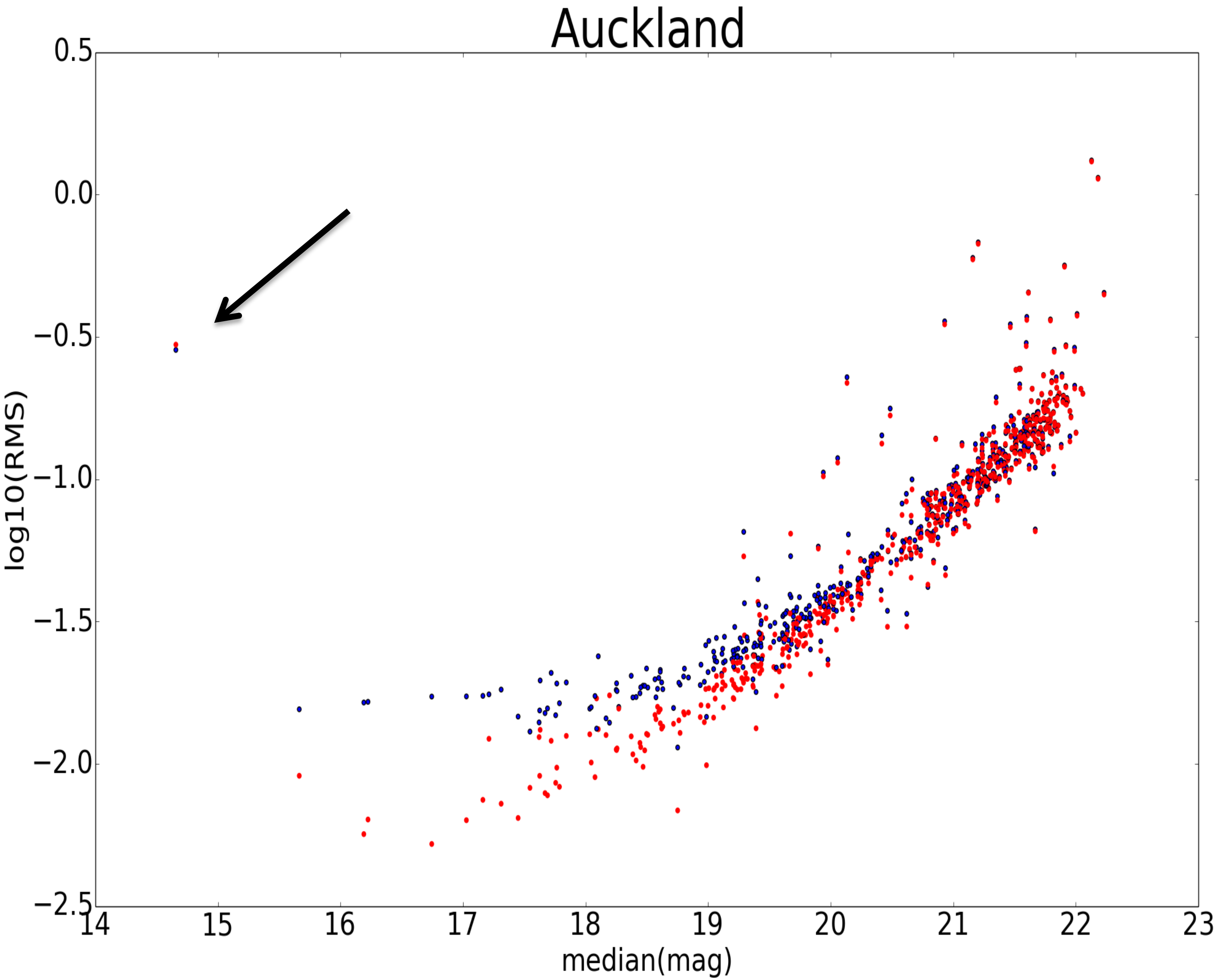
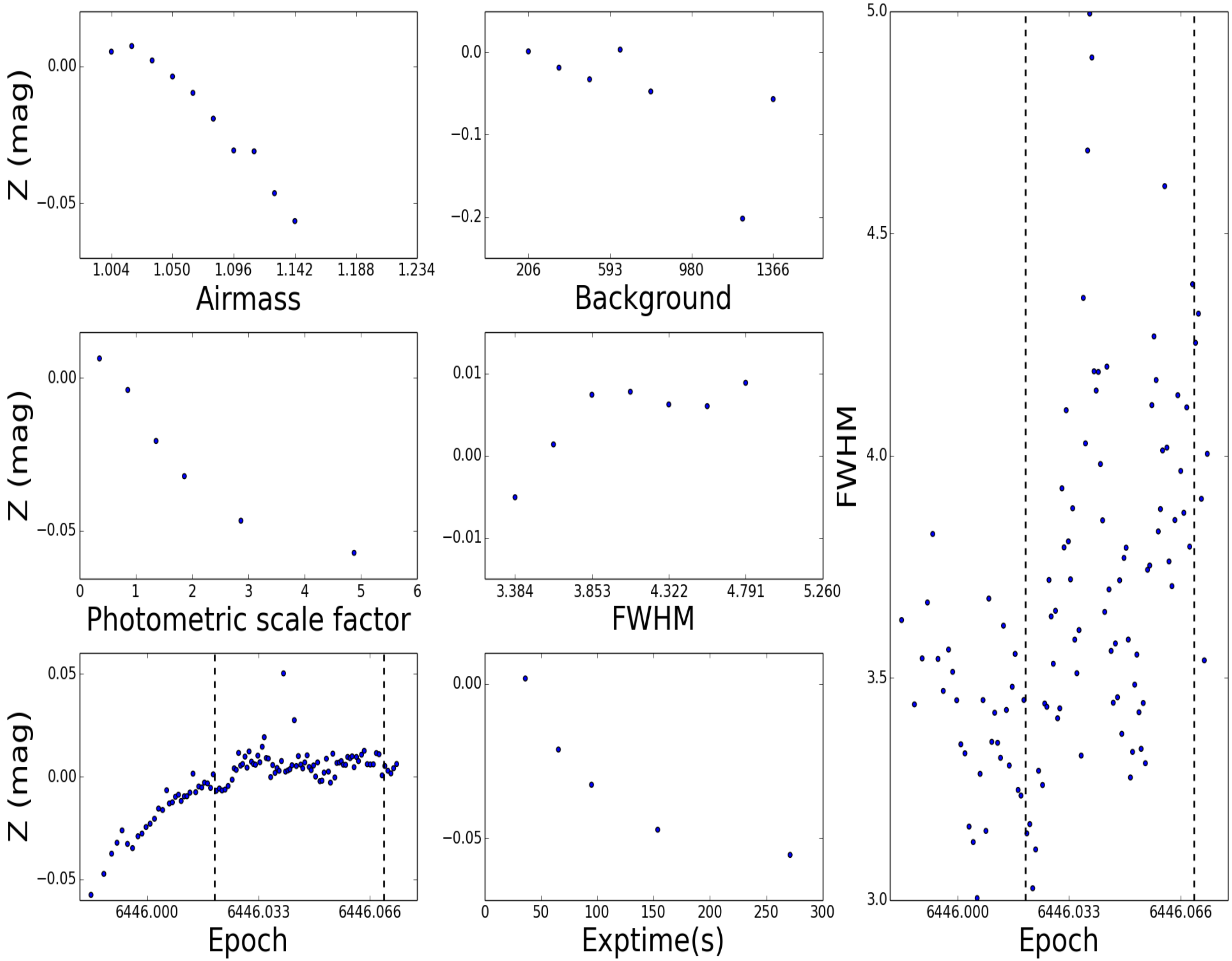
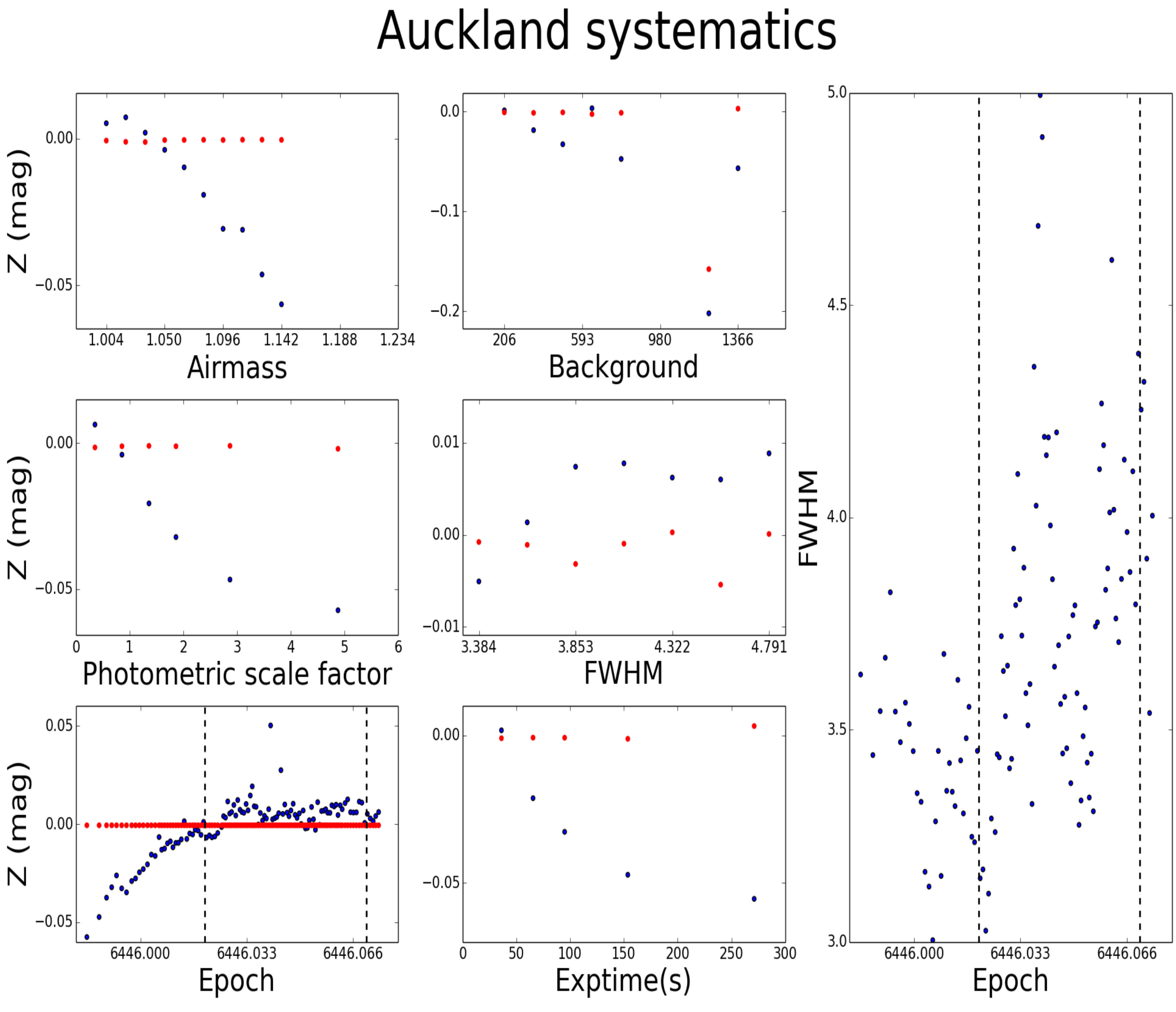
Honeycutt(1992),Bramich&Freudling(2012)



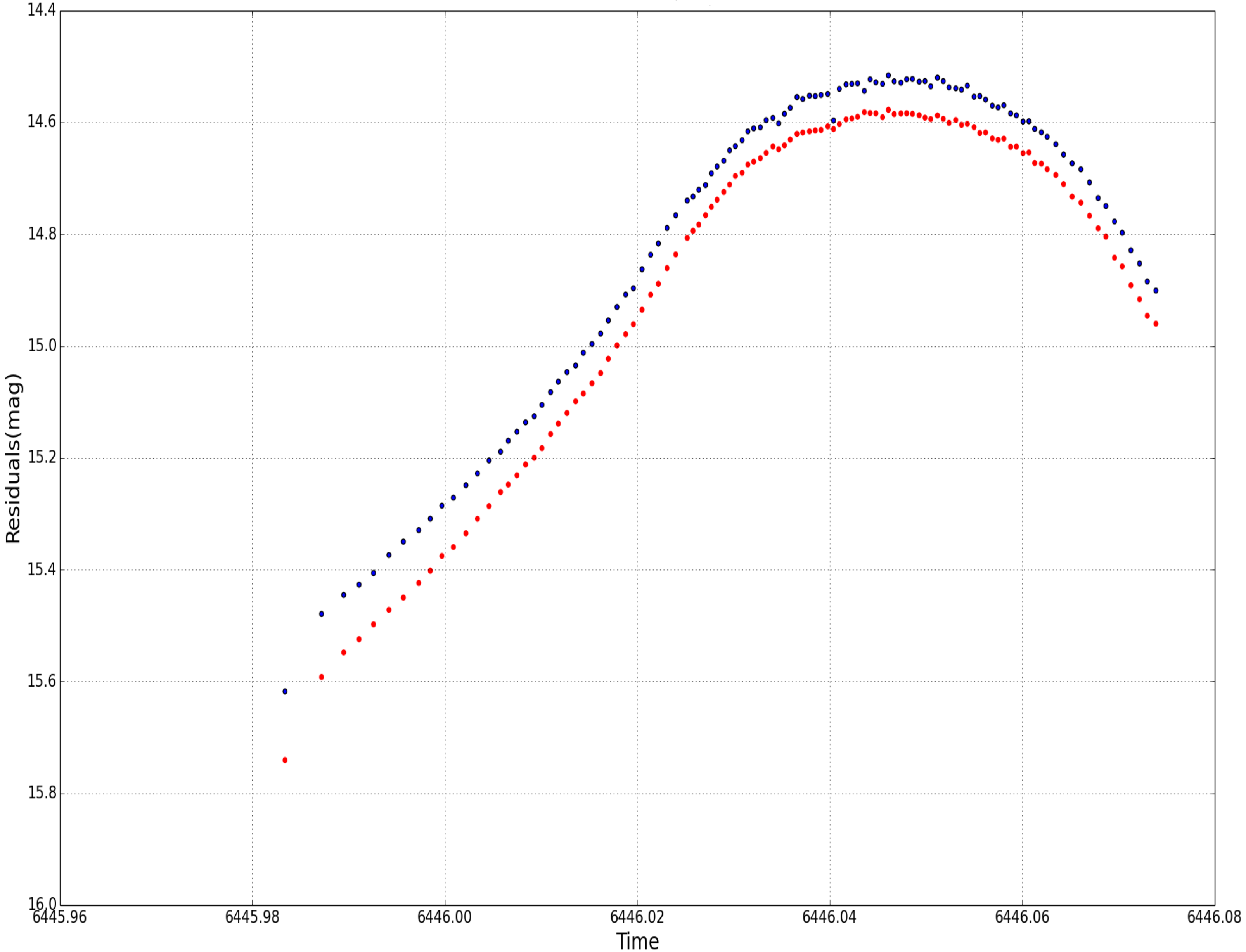
Auckland
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
log10(RMS)
14
15
16
17
18
19
20
21
22
23
median(mag)

Auckland systematics



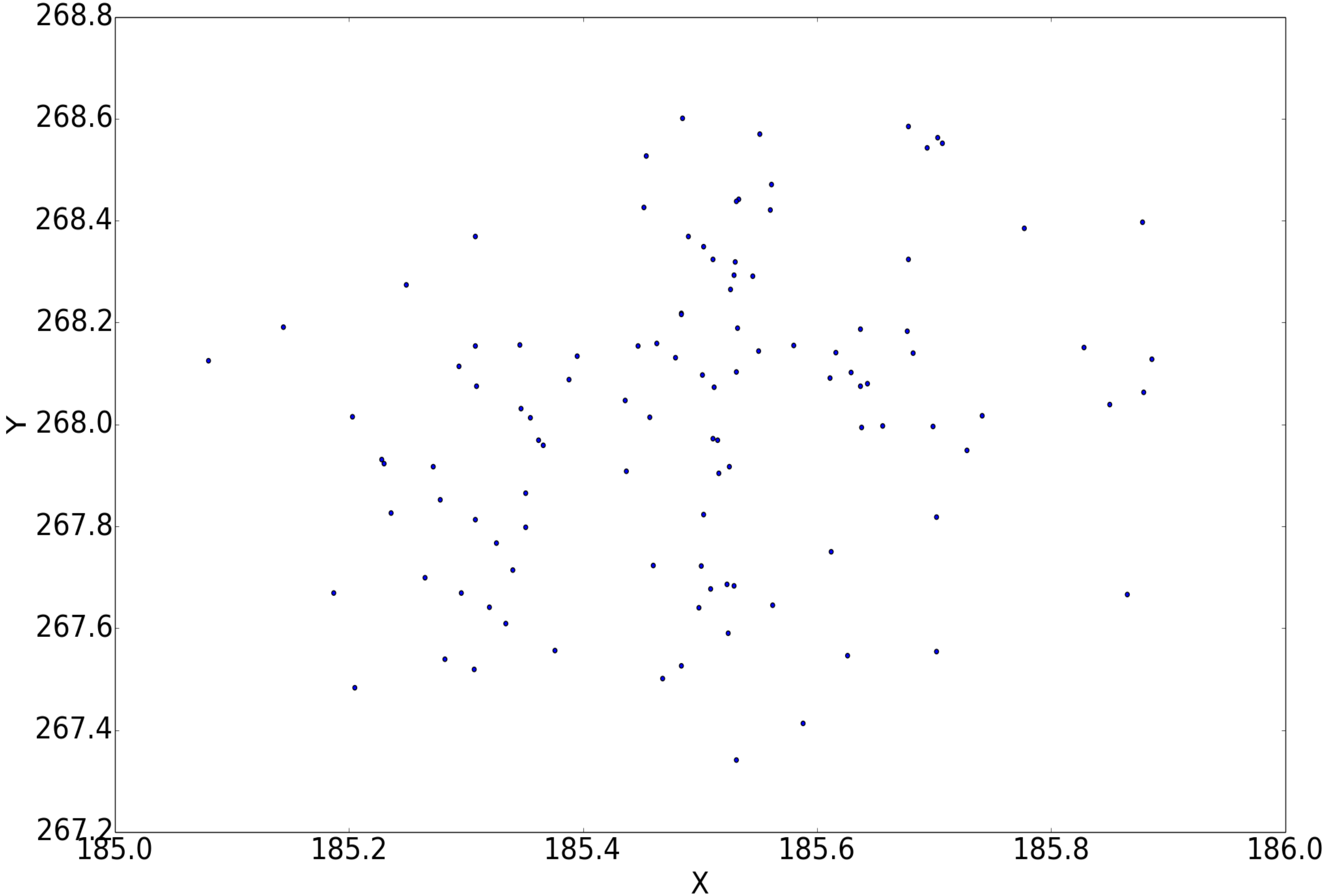


Auckland systematics
Z (mag)
Airmass
Background
Photometric scale factor
FWHM
Epoch
Exptime(s)
1.004
1.050
1.096
1.142
1.188
1.234
206
593
980
1366
3.384
3.853
4.322
4.791
6446.000
6446.033
6446.066

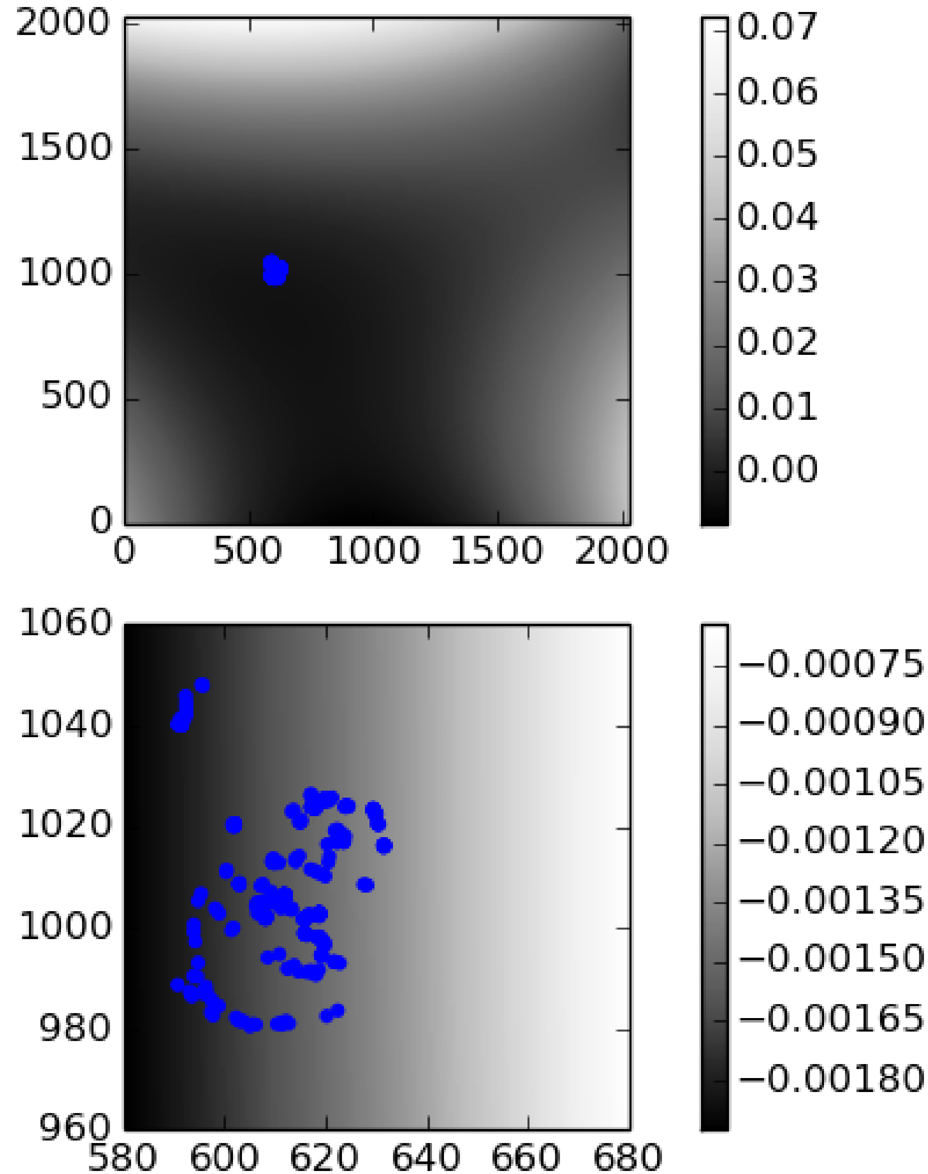


14.4
14.6
14.8
15.0
15.2
15.4
15.6
15.8
16.0
Residuals(mag)
6445.96
6445.98
6446.00
6446.02
6446.04
6446.06
6446.08
Time

AUCKLAND CCD Positions



LSCB CCD Positions



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Auckland dataset

Quantity	Peak to peak Amplitude (mag)
Exposure time	0.05
Airmass	0.05
PSF FWHM	0.02
Photometric scale factor	0.05
Time	0.07
Detector coordinates	*
Background	0.05

LSCB dataset

Quantity	Peak to peak Amplitude (mag)
Exposure time	0.0003
Airmass	0.0006
PSF FWHM	0.0005
Photometric scale factor	0.001
Time	0.0025
Detector coordinates	0.001
Background	0.0004

IV. Conclusion

Systematic errors can be at the same level as low planetary signals!

Systematic erros can differ a lot for different data sets.

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IV. Plans

Correcting systematics for other data sets

New set of modeling

Confirm/infirm the planetary presence

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