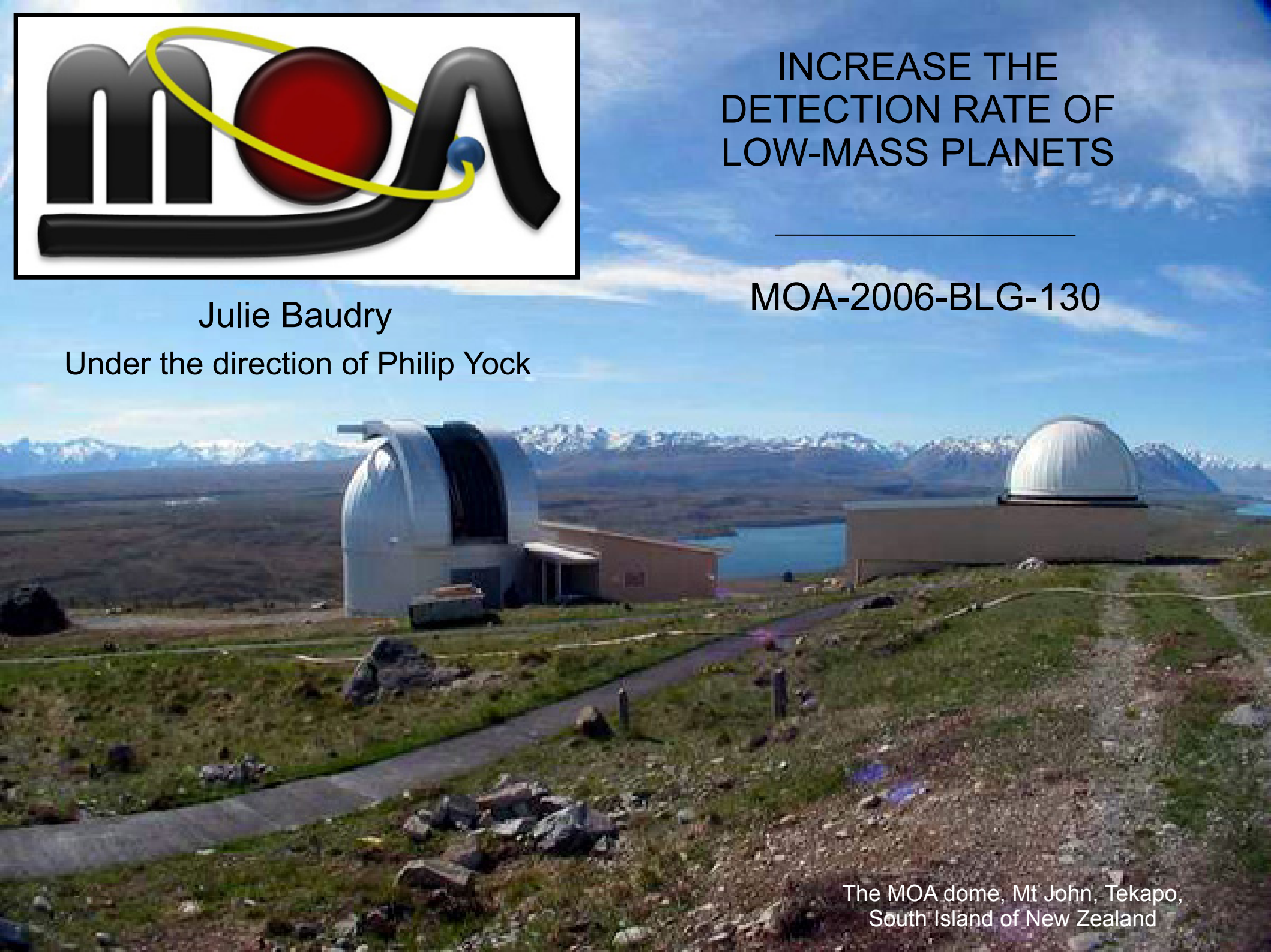
INCREASE THE DETECTION RATE OF LOW-MASS PLANETS

MOA-2006-BLG-130

Julie Baudry

Under the direction of Philip Yock



The MOA dome, Mt John, Tekapo, South Island of New Zealand

SUMMARY

- Introduction

SUMMARY

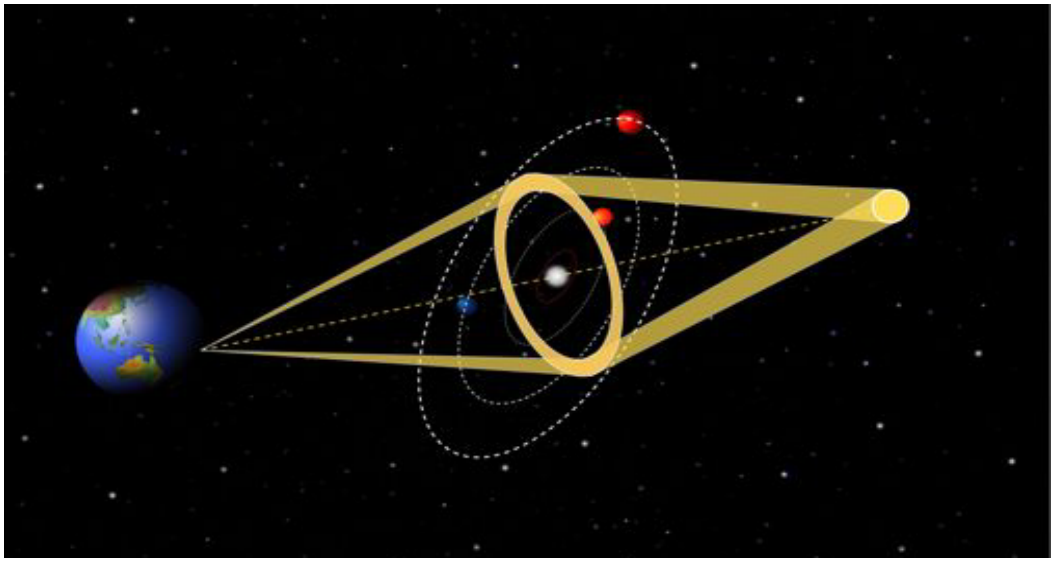
- Introduction

- Planetary perturbation and magnification

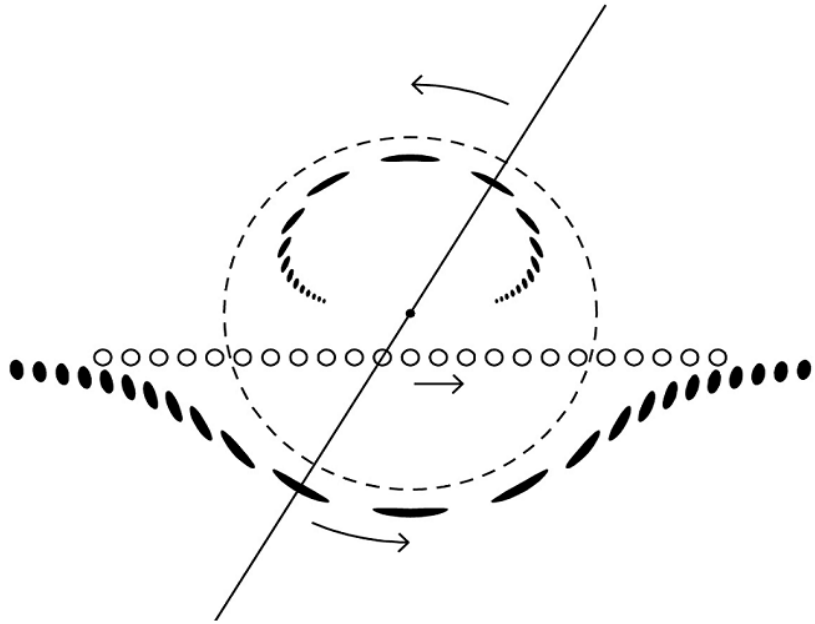
SUMMARY

- Introduction
- Planetary perturbation and magnification
- MOA – 2006 – BLG – 130

I – Gravitational Microlensing



Light from the source star is bent into an Einstein ring around the lens star

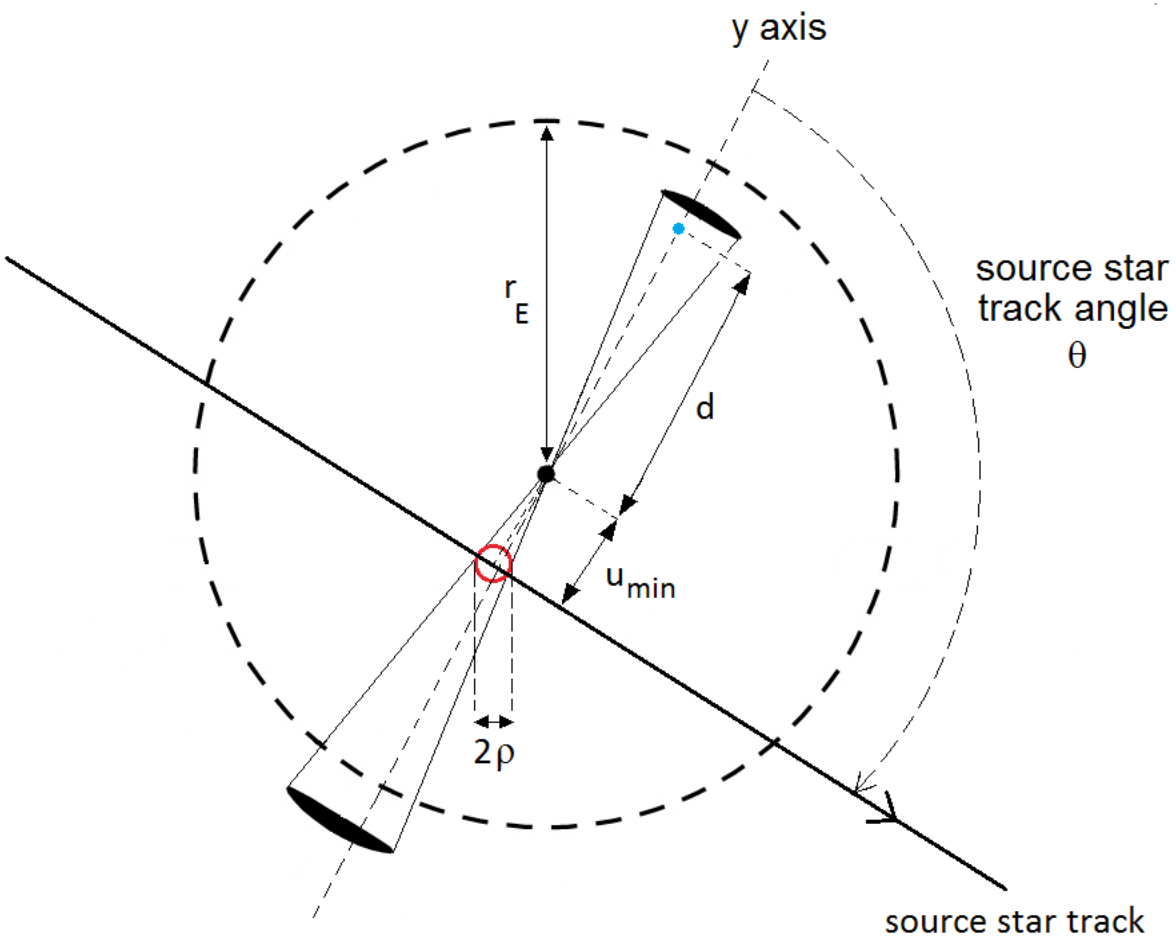


Bohdan Paczynski, Ann. Rev. Astron.. Astrophys. 34, 419 (1996)

$$r_E = \left(\frac{4\,G\,M_l}{c^2} \cdot \frac{D_l\,(D_l - D_s)}{D_s} \right)^{1/2}$$

II – Planetary perturbation and magnification

Binary lens configuration



Planet parameters:

· q = mass ratio (planet / lens)

· d = distance lens – planet

· angle from the y axis is fixed at 0

Track parameters:

· u_{min} = minimum impact parameter

· ρ = source star radius

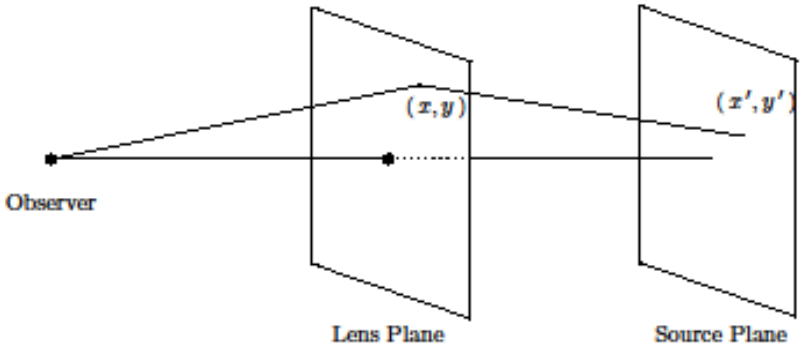
· θ = source track angle

· the time to cross the Einstein ring and the time of minimum impact are choosen randomly, in the range of real events

· no parallax

(All distances are given in unit of r_E)

II – Planetary perturbation and magnification



$$x' = x - \frac{m_1 x}{x^2 + y^2} - \sum_{i=1}^{n} \frac{m_i (x - x_i)}{(x - x_i)^2 + (y - y_i)^2},$$

$$y' = y - \frac{m_1 y}{x^2 + y^2} - \sum_{i=1}^{n} \frac{m_i (y - y_i)}{(x - x_i)^2 + (y - y_i)^2}.$$

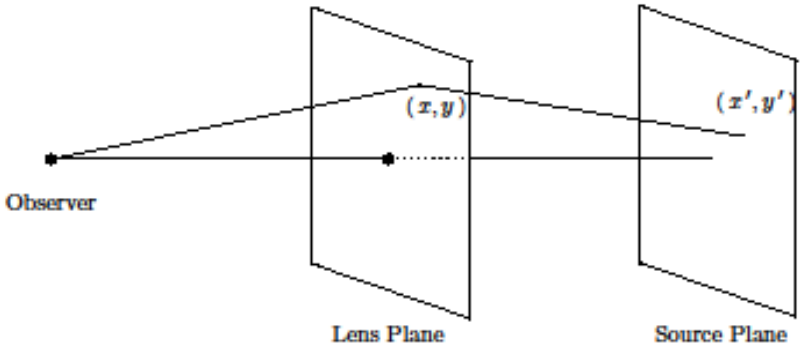
Creating theoretical microlensing lightcurves from magnification maps, L. Philpott, 2005

✓ Magnification maps are computed for 9 systems [lens + planet] using the inverse ray shooting technique

⇨ fractionnal maps

·*Lydia Philpott, 2005; C.S. Botzler,2006; Sarah Holderness, 2008; Yvette Perrott, 2009.*

II – Planetary perturbation and magnification



$$x' = x - \frac{m_1 x}{x^2+y^2} - \sum_{i=1}^{n} \frac{m_i(x-x_i)}{(x-x_i)^2+(y-y_i)^2},$$
$$y' = y - \frac{m_1 y}{x^2+y^2} - \sum_{i=1}^{n} \frac{m_i(y-y_i)}{(x-x_i)^2+(y-y_i)^2}.$$

Creating theoretical microlensing lightcurves from magnification maps, L. Philpott, 2005

✓ Magnification maps are computed for 9 systems [lens + planet] using the inverse ray shooting technique

⇨ fractionnal maps

✓ Theoritical light curves

⇨ No parallax

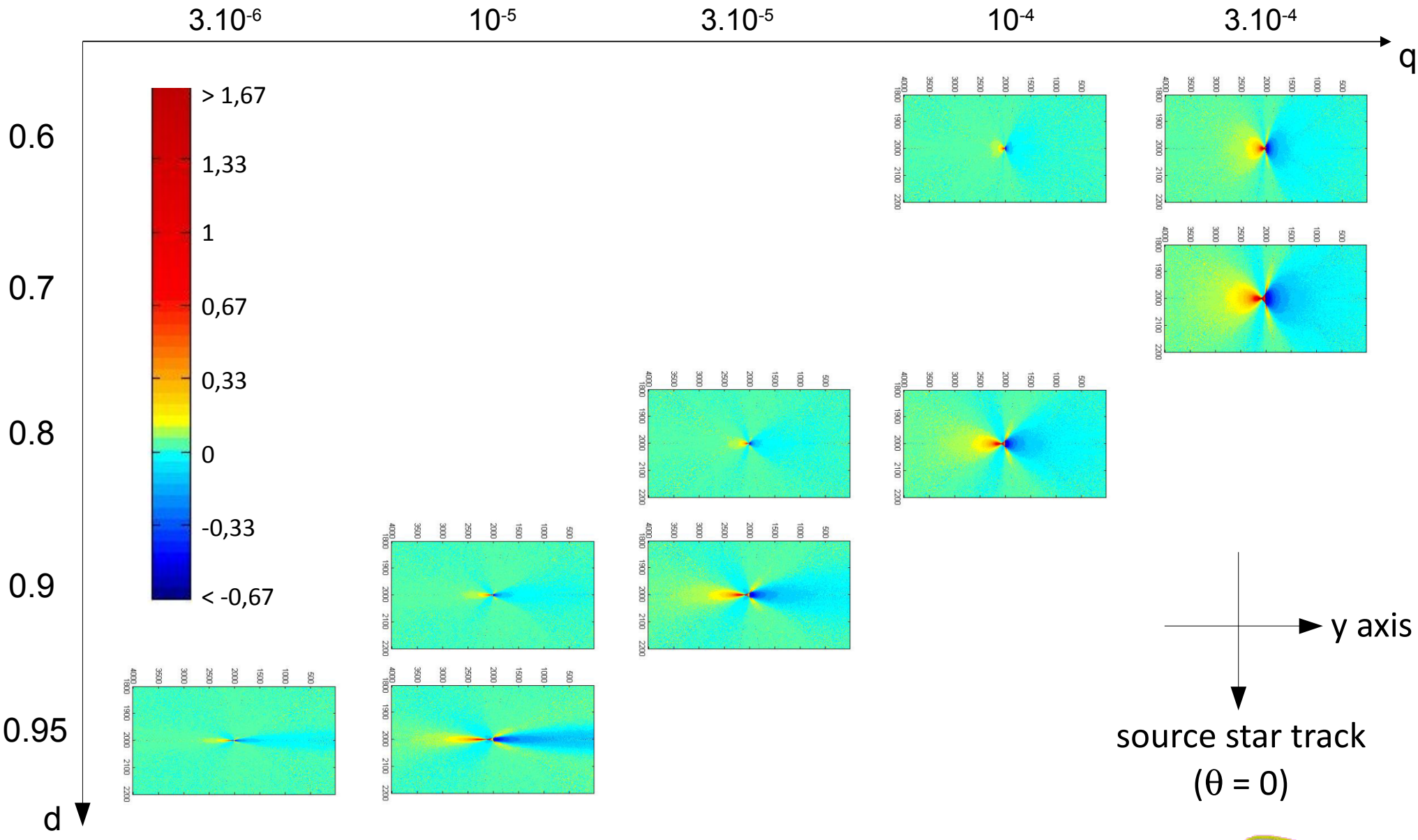
⇨ Source track angle : $\theta = 0$

⇨ for each system, 3 values of the source star radius are tested
ρ = {0,001; 0,002 ; 0,005}

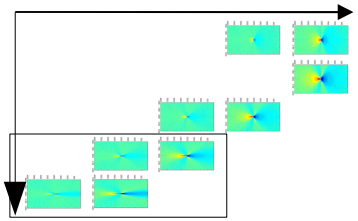
⇨ 13 values of u_{min} are have been simulated, in a range of $|u_{min}| \in [\,0\,;\,0{,}03\,]$

·*Lydia Philpott, 2005; C.S. Botzler,2006; Sarah Holderness, 2008; Yvette Perrott, 2009.*

II – Planetary perturbation and magnification



II – Planetary perturbation and magnification

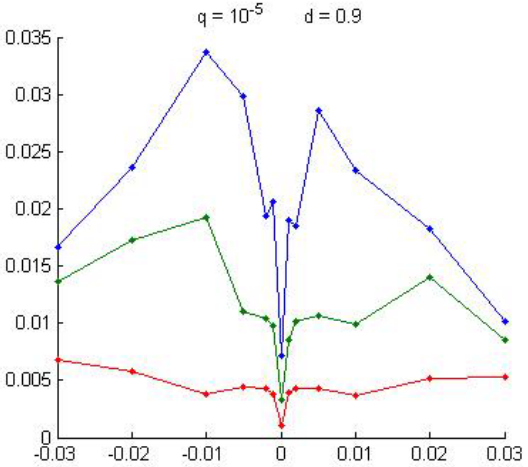


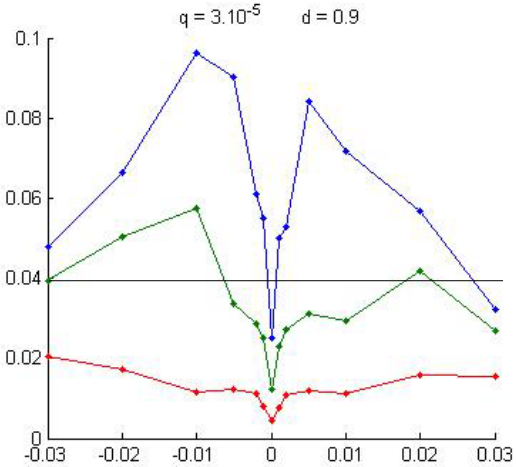
detectability threshold ~4%

ρ = 0.005

ρ = 0.002

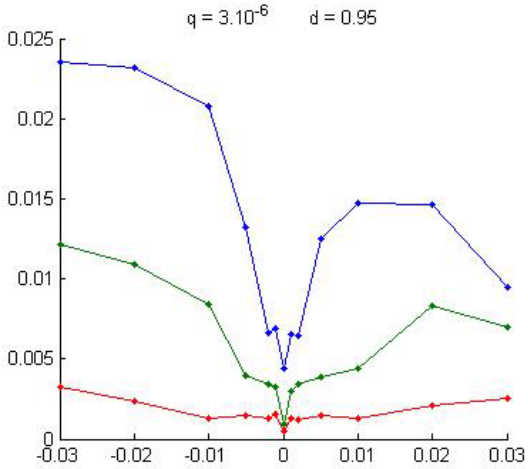
ρ = 0.001

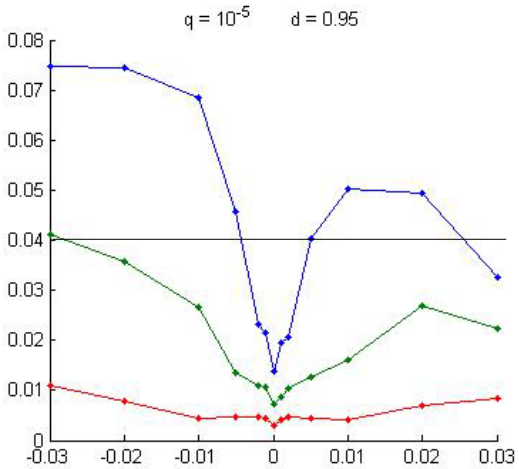




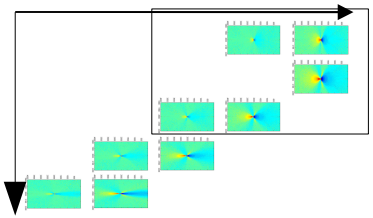
% of deviation to the light curve

u_{min}



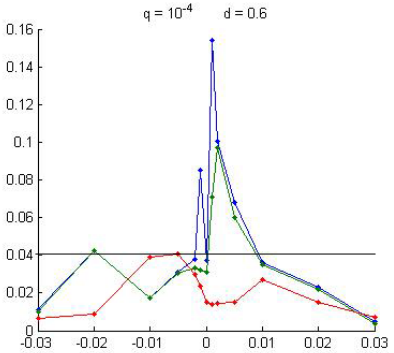


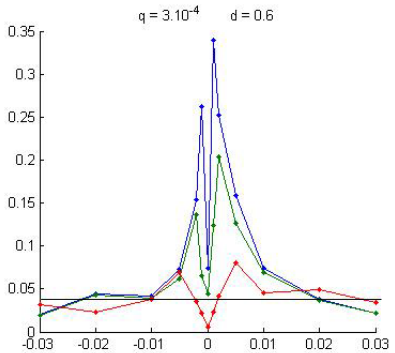
II – Planetary perturbation and magnification

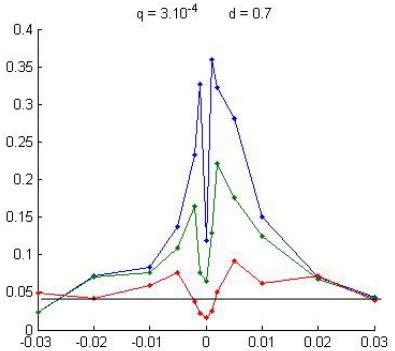


detectability threshold ~4%

ρ = 0.005
ρ = 0.002
ρ = 0.001

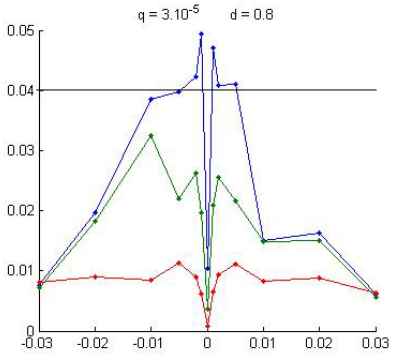


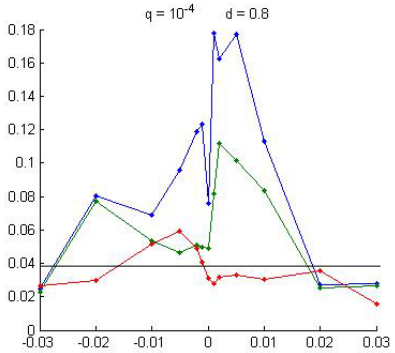




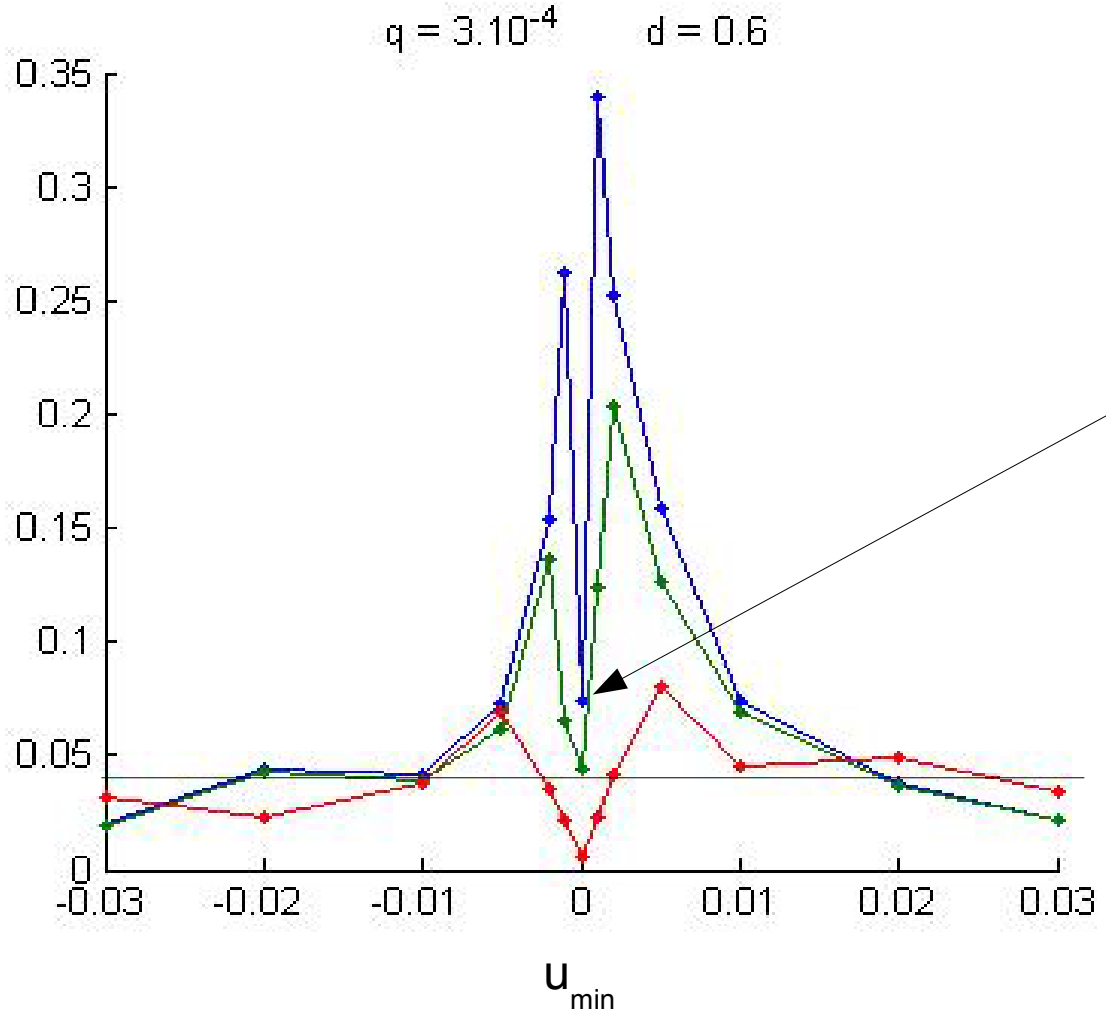
% of deviation to the light curve

u_{min}





II – Planetary perturbation and magnification

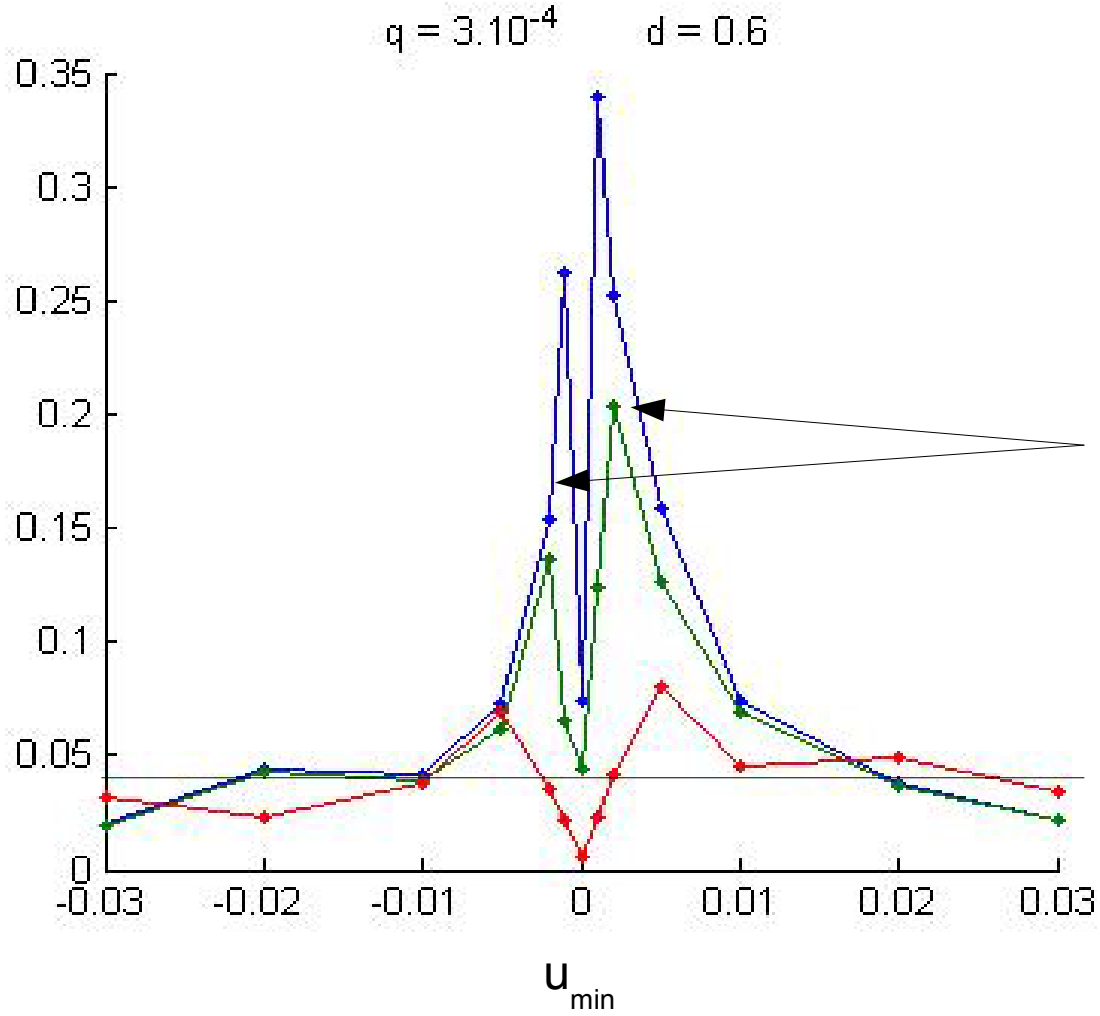


% of deviation to the light curve

|umin| < 0.001

detection threshold

II – Planetary perturbation and magnification

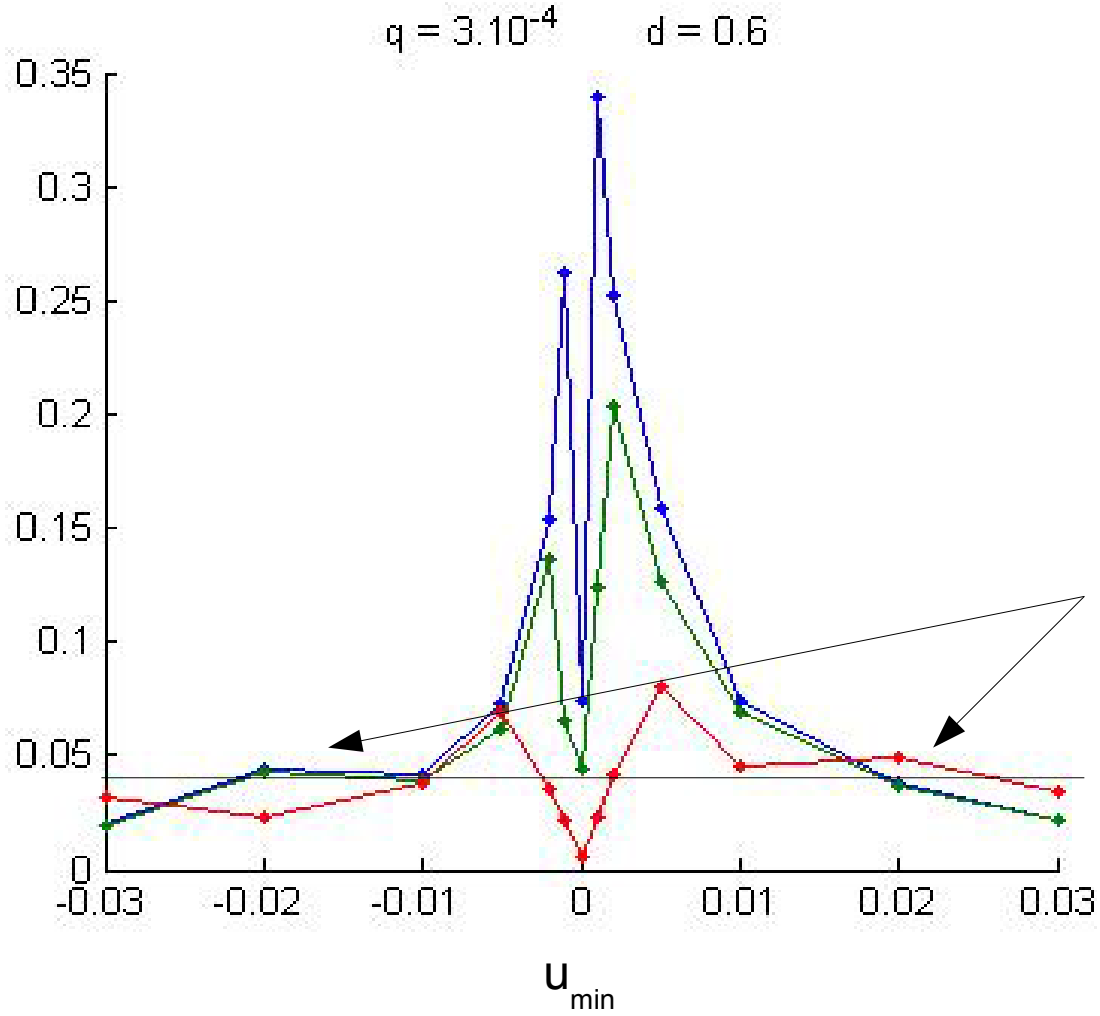


% of deviation to the light curve

0.001 < |umin| <0 .005

detection threshold

II – Planetary perturbation and magnification



% of deviation to the light curve

0.005 < |umin|

detection threshold

II – Planetary perturbation and magnification

➔ We can distinguish 3 zones:

	I	II	III
Geometry			
Range of u_{min}			
Consequences on the planetary perturbation			

II – Planetary perturbation and magnification

➔ We can distinguish 3 zones:

	I	II	III
Geometry	The source transits the lens		
Range of u_{min}	$u_{min} < \rho$		
Consequences on the planetary perturbation	Low mass planets with $q < 3.10^{-5}$ undetectable		

II – Planetary perturbation and magnification

➔ We can distinguish 3 zones:

	I	II	III
Geometry	The source transits the lens	The planet is closer to the Einstein ring than the length of an arc.	
Range of u_{min}	$u_{min} < \rho$	$\rho < u_{min} < \frac{2\rho}{1-d}$	
Consequences on the planetary perturbation	Low mass planets with $q < 3.10^{-5}$ undetectable	Low mass planets with $q > 10^{-5}$ detectable and perturbation approximately independent of umin, i.e. sensitivity independent of Amax	

II – Planetary perturbation and magnification

➔ We can distinguish 3 zones:

	I	II	III
Geometry	The source transits the lens	The planet is closer to the Einstein ring than the length of an arc.	The planet is further away than the length of an arc.
Range of u_{min}	$u_{min} < \rho$	$\rho < u_{min} < \frac{2\rho}{1-d}$	$\frac{2\rho}{1-d} < u_{min}$
Consequences on the planetary perturbation	Low mass planets with $q < 3.10^{-5}$ undetectable	Low mass planets with $q > 10^{-5}$ detectable and perturbation approximately independent of umin, i.e. sensitivity independent of Amax	Sensitivity greatest at high magnification, but low mass planets undetectable

II – Planetary perturbation and magnification

➔ We can distinguish 3 zones:

	I	II	III
Geometry	The source transits the lens	The planet is closer to the Einstein ring than the length of an arc.	The planet is further away than the length of an arc.
Range of u_{min}	$u_{min} < \rho$	$\rho < u_{min} < \frac{2\rho}{1-d}$	$\frac{2\rho}{1-d} < u_{min}$
Consequences on the planetary perturbation	Low mass planets with $q < 3.10^{-5}$ undetectable	Low mass planets with $q > 10^{-5}$ detectable and perturbation approximately independent of umin, i.e. sensitivity independent of Amax	Sensitivity greatest at high magnification, but low mass planets undetectable

II – Planetary perturbation and magnification

- Transit events insensitive to low-mass planets

II – Planetary perturbation and magnification

- Transit events insensitive to low-mass planets

- Moderate magnification events sensitive to low mass planets quite close to the ring

- More events occur at lower magnifications, but larger telescopes are needed to monitor them

II – Planetary perturbation and magnification

→ Transit events insensitive to low-mass planets

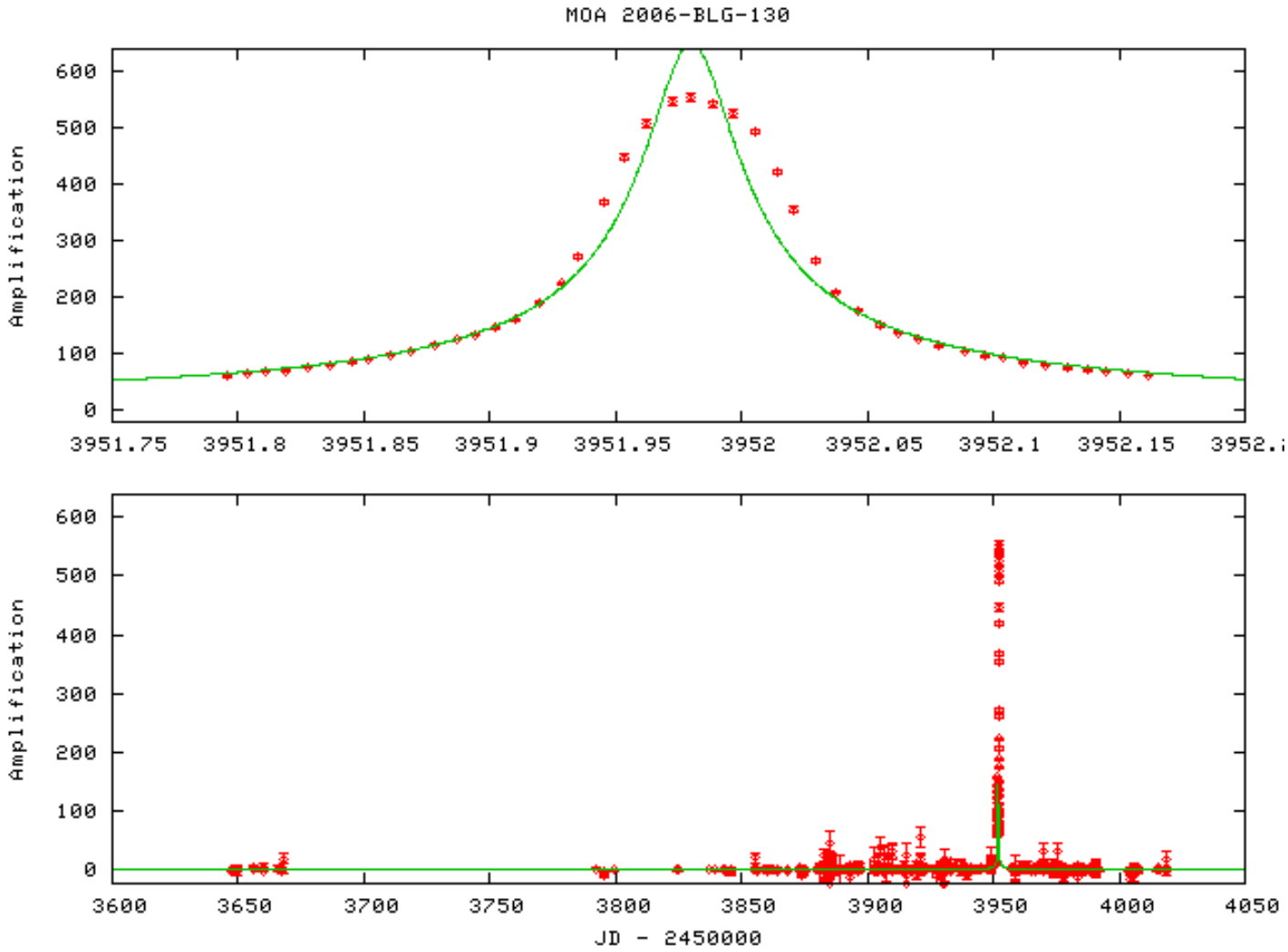
→ Moderate magnification events sensitive to low mass planets quite close to the ring

→ More events occur at lower magnifications, but larger telescopes are needed to monitor them

→Low mass planets not detectable if they are not close to the ring

III – MOA-2006-BLG-130 : event in zone I

MOA data



http://www.phys.canterbury.ac.nz/moa/microlensing_alerts.html

III – MOA-2006-BLG-130 : event in zone I

✓ Using the same code than previously, magnification maps are computed for 27 couples (q ; d):

$$\begin{cases} q = 10^{-4} , 3.10^{-4} , 10^{-3} \\ d = 0.3 , 0.5 , 0.7 , 0.8 , 0.85 \end{cases} \qquad \begin{cases} q = 3.10^{-6} , 10^{-5} , 3.10^{-5} \\ d = 0.8 , 0.85 , 0.9 , 0.95 \end{cases}$$

III – MOA-2006-BLG-130 : event in zone I

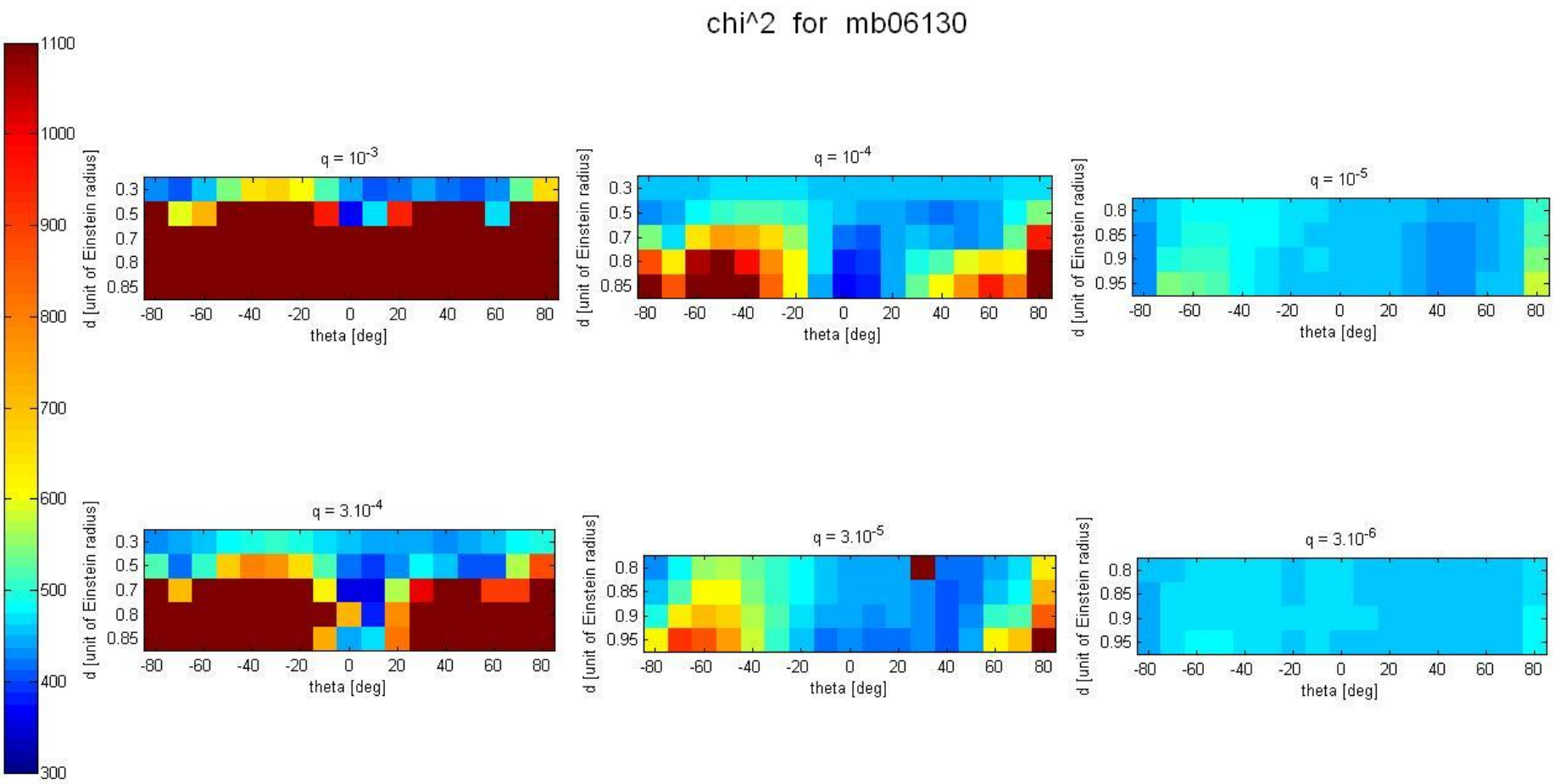
✓ Using the same code than previously, magnification maps are computed for 27 couples (q ; d):

$$\begin{cases} q = 10^{-4} , 3.10^{-4} , 10^{-3} \\ d = 0.3 , 0.5 , 0.7 , 0.8 , 0.85 \end{cases} \qquad \begin{cases} q = 3.10^{-6} , 10^{-5} , 3.10^{-5} \\ d = 0.8 , 0.85 , 0.9 , 0.95 \end{cases}$$

✓ We use a χ^2 marginalisation method to determine the best model:

- Fixed parameter : source track angle θ
- No parallax

III – MOA-2006-BLG-130 : event in zone I



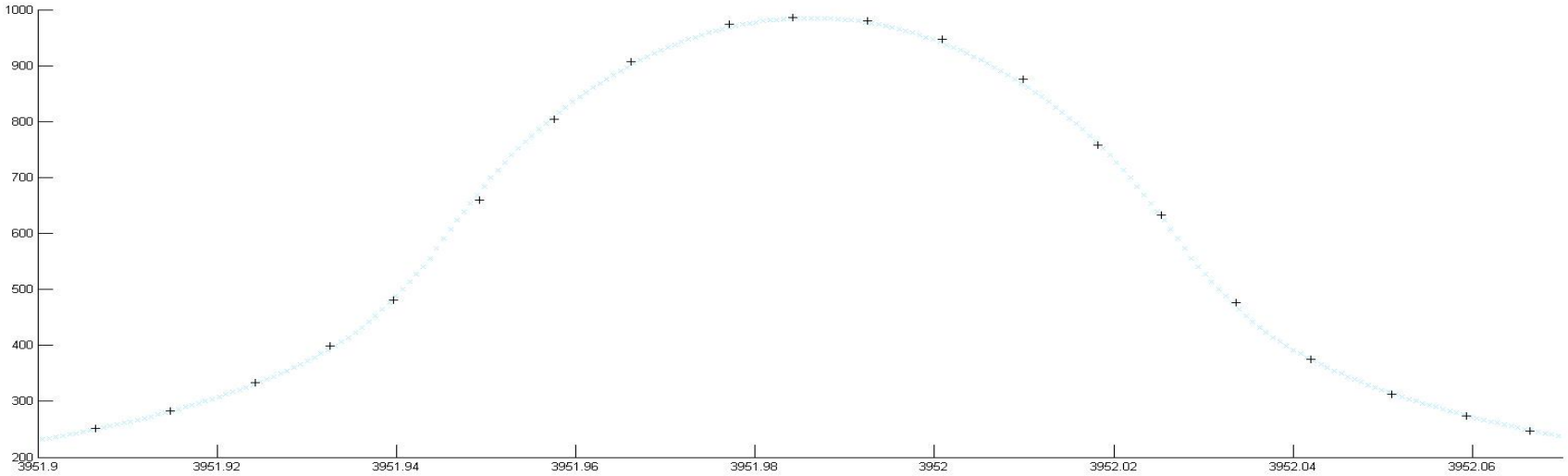
III – MOA-2006-BLG-130 : event in zone I

· Best fits and single lens parameters:

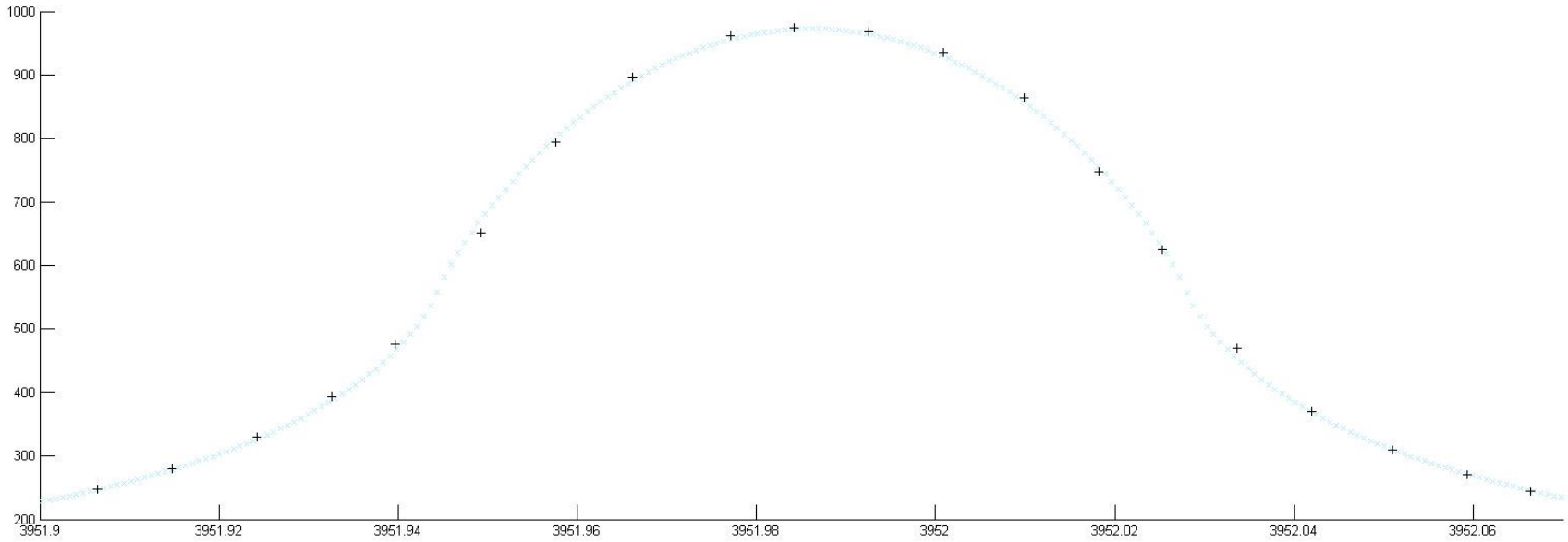
q	d	ρ	θ	u_{min}	t_E	t_0	χ^2
3.10^{-4}	0.7	0.0022 ± 0.0001	0	0.0002 ± 0.0001	3951.9862 ± 0.0002	18.91 ± 0.005	359.18
10^{-4}	0.85	0.0022 ± 0.0001	0	-0.0001 ± 0.0001	3951.9862 ± 0.0002	18.955 ± 0.005	364.44
0	0	0.0022 ± 0.0001	-	-0.0002 ± 0.0001	3951.9862 ± 0.0002	19.1 ± 0.005	464.93

III – MOA-2006-BLG-130 : event in zone I

$q = 10^{-4}$
$d = 0.85$



single lens



JD - 2450000

III – MOA-2006-BLG-130 : event in zone I

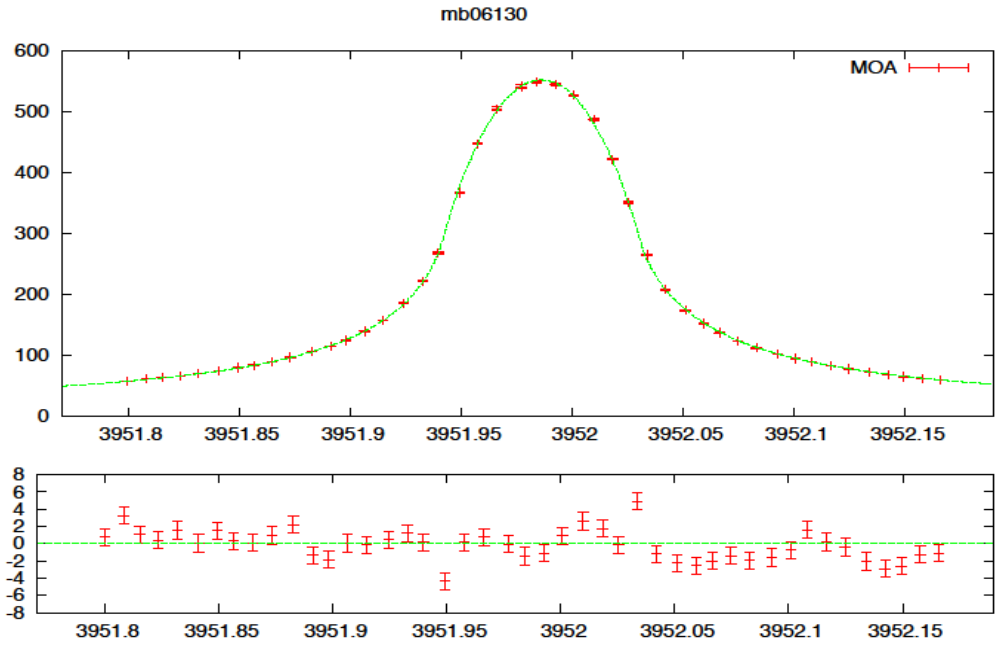
→ Finer simulations could be done in zones of lowest chi².

III – MOA-2006-BLG-130 : event in zone I

- Finer simulations could be done in zones of lowest chi².
- Data are too sparse to be assertive on the presence of a planet.

III – MOA-2006-BLG-130 : event in zone I

- Finer simulations could be done in zones of lowest chi².
- Data are too sparse to be assertive on the presence of a planet.
- Other phenomena could be the cause the deviation to the light curve :



By Ian Bond, University of Auckland, New Zealand

→ Periodic phenomenon ?

Thanks

Thanks to the Physics Department of the UoA, New Zealand, to the Earth and Sky company and astronomers of the Mt John Observatory.

Very special thanks to Philip Yock.

AND THANK YOU FOR YOUR ATTENTION!