A systematic search for minima in caustic-crossing microlensing events

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Introduction

- ~ 1000 microlensing events/ year
- ~ 10% anomalous
- Many difficult to classify
- Modelling is complicated business!

Why is modelling difficult?

- A large and complex parameter space
- Calculating lightcurves is computationally demanding (finite-source effects)
- Lots of local minima
- Degeneracies, incomplete sampling

“Classic” fitting approach

- Use 7 “standard” parameters (for simplest case- no parallax/ xallarap, rotation, ...)
- Use genetic algorithm, amoeba, Powell, MCMC to explore parameter space
- GA is slow, MCMC, amoeba and Powell can’t cover large parts of parameter space

Parametrisation

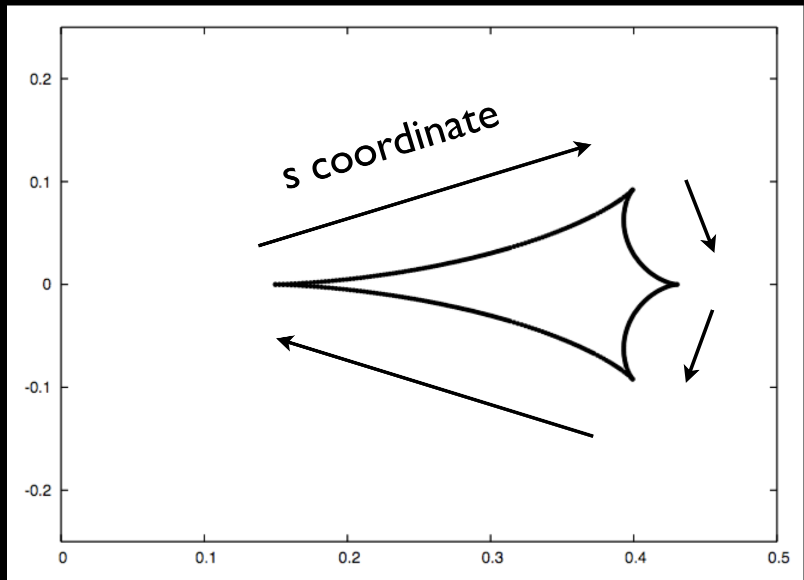
- “Standard” parameters are not well related to data features
- We need parameters that we can easily “guess” from data

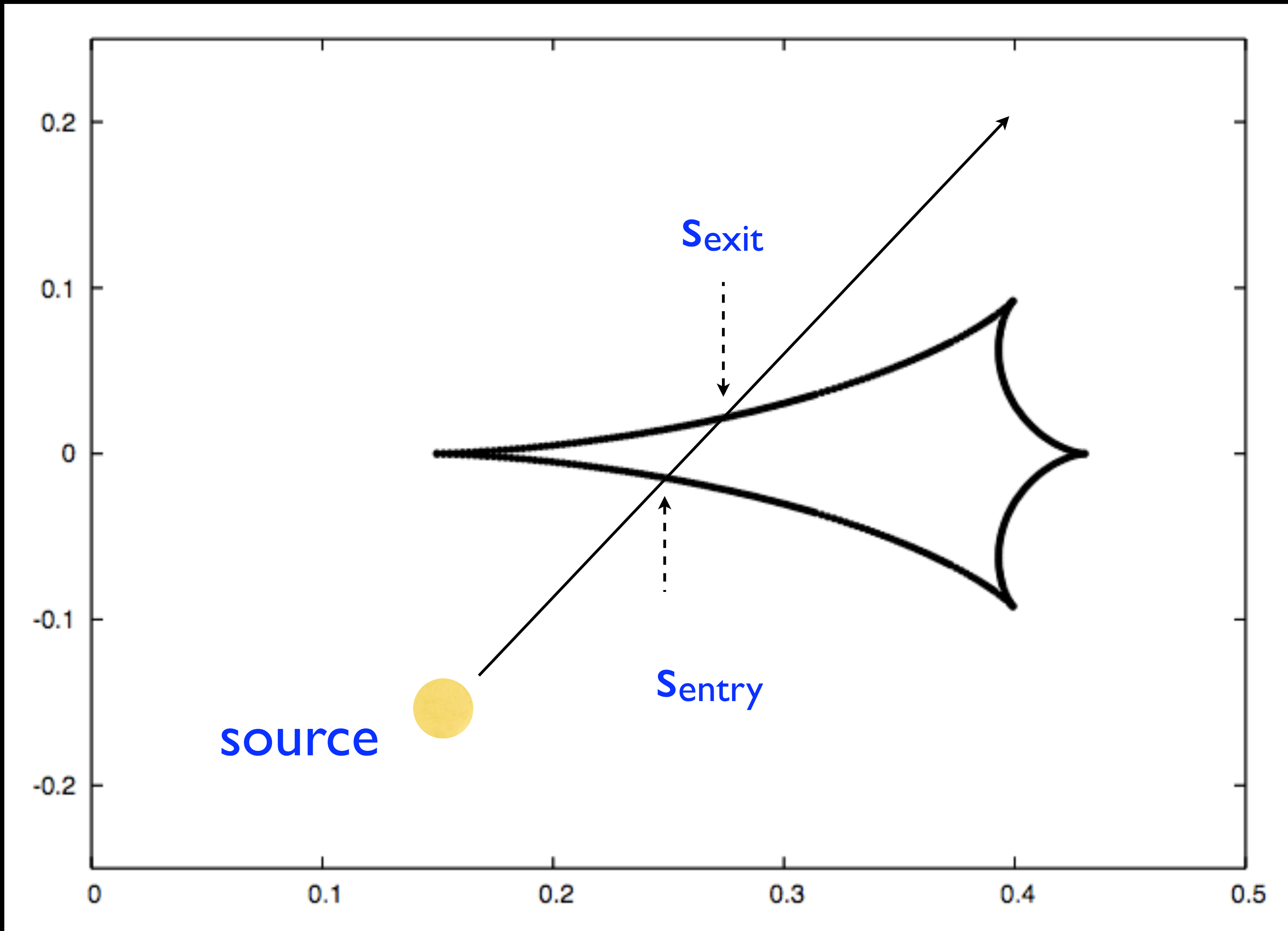
Our parameters

- Replace t_0, t_E, u_0, α with t_{entry}, t_{exit}, s_{entry}, s_{exit} as proposed by Cassan (2008)
- t_{entry}, t_{exit}, correspond to the times of caustic entry and exit- easy to estimate

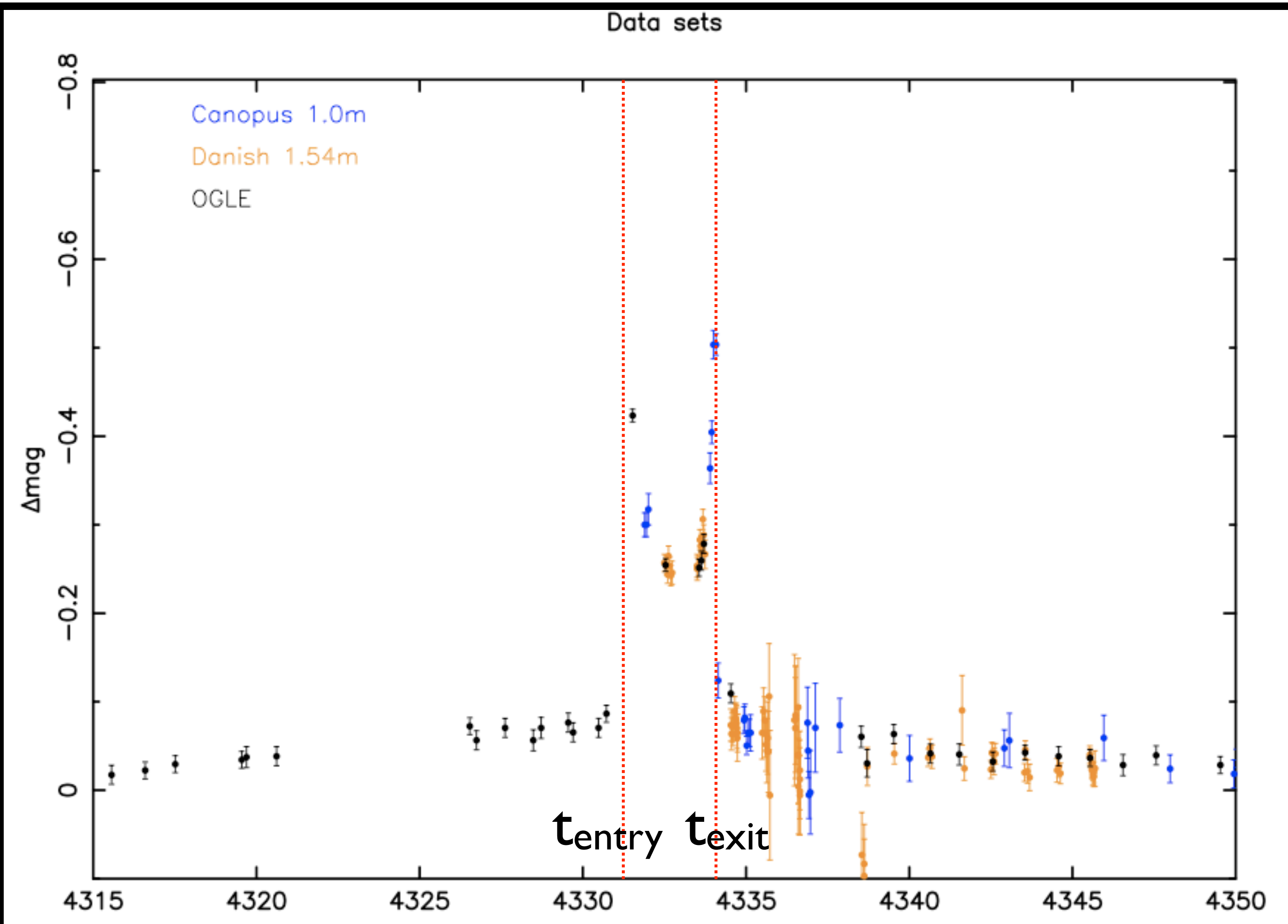
Our parameters

- s_{entry}, s_{exit} correspond to location of the source on the caustic at t_{entry}, t_{exit}.





0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
0.4
0.5
s_{exit}
s_{entry}
source



Data sets
Canopus 1.0m
Danish 1.54m
OGLE
Δmag
−0.8
−0.6
−0.4
−0.2
0
4315
4320
4325
4330
4335
4340
4345
4350
t_{entry}
t_{exit}

Fitting procedure

- We fit for t_{entry}, t_{exit}, s_{entry}, s_{exit}, d, q, ρ_* (or t_*)
- This covers all appropriate static binary lens configurations
- This ensures we only explore models that feature caustic crossings at the right times
- Easily converted back to standard parameters

Fitting procedure

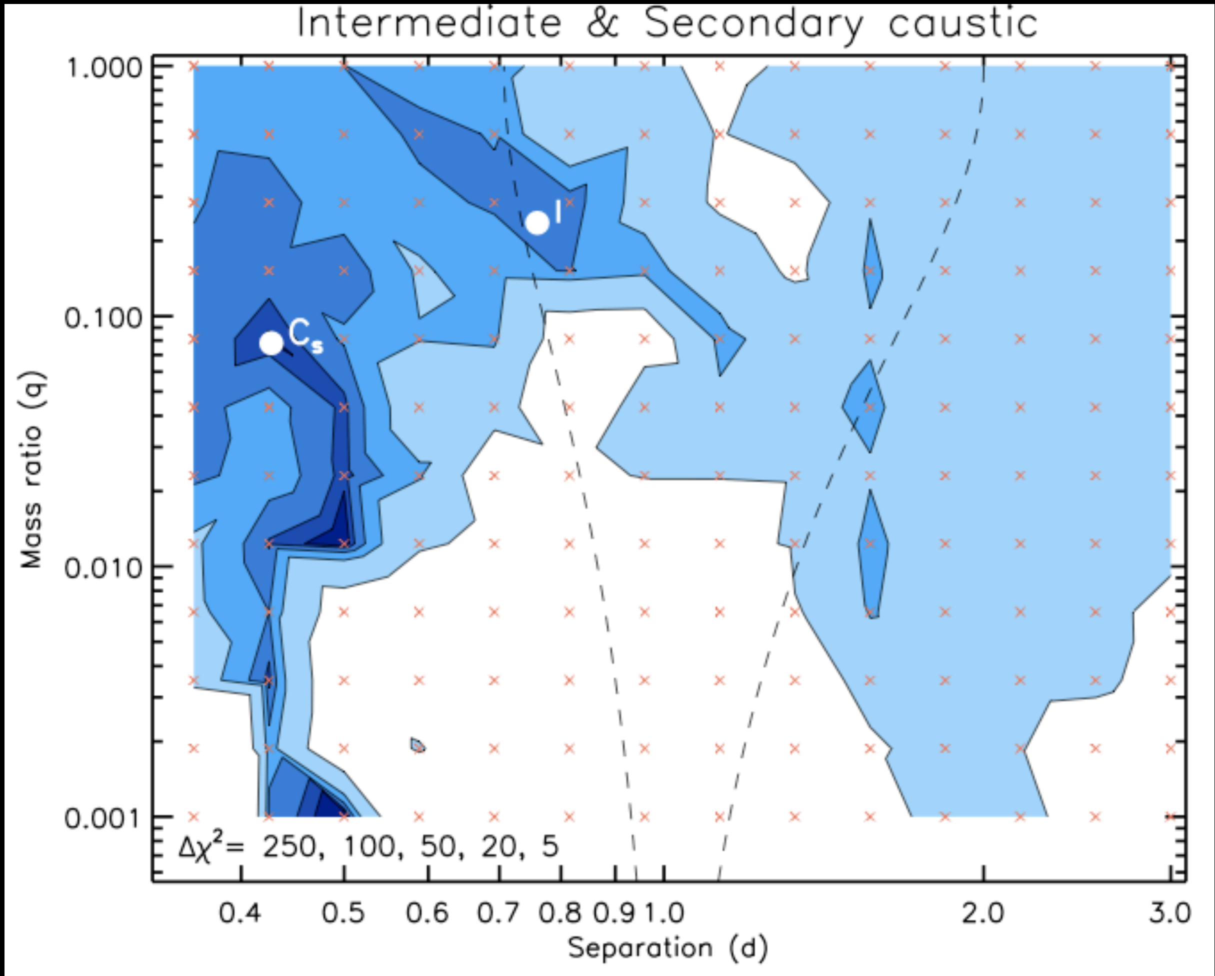
- First step is to explore a caustic with these alternative parameters.
- For a given pair of (d, q), we optimise the other 5 parameters with a GA code (gobi)
- Starting from the best-fit model found by the GA, we start MCMC runs, still with (d, q) fixed, with standard parameters.

Fitting procedure

- Repeat this for a grid of (d, q) values to find a χ^2 map in the (d, q) plane
- Repeat this for each type of caustics (central or secondary)

- This means we find the lowest-χ^2 model for the full range of possible configurations
- Result is a χ^2 map for
  - Models in which the source crosses a secondary caustic
  - Models in which the source crosses a central caustic

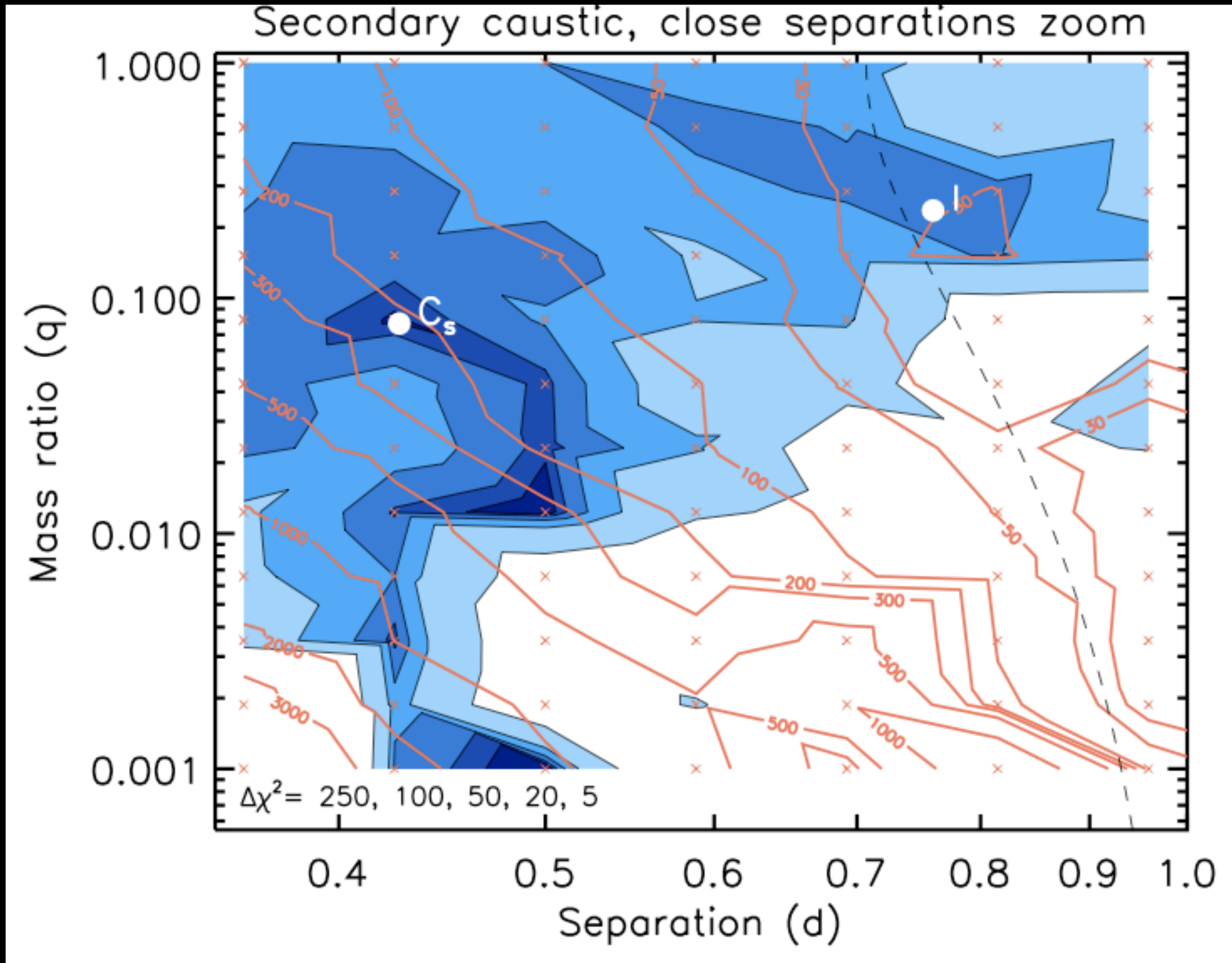
χ^2 map for OB07472



N. Kains et al. 2008, in prep.

χ^2 map for OB07472

- Several "minima regions"
- Minima exist in parameter space with low value of q
- To understand this, interesting to overplot t_E contour



Secondary caustic, close separations zoom
Mass ratio (q)
Separation (d)
1.000
0.100
0.010
0.001
0.4
0.5
0.6
0.7
0.8
0.9
1.0
C_s
I
$\Delta\chi^2$= 250, 100, 50, 20, 5

Finding best-fit minima

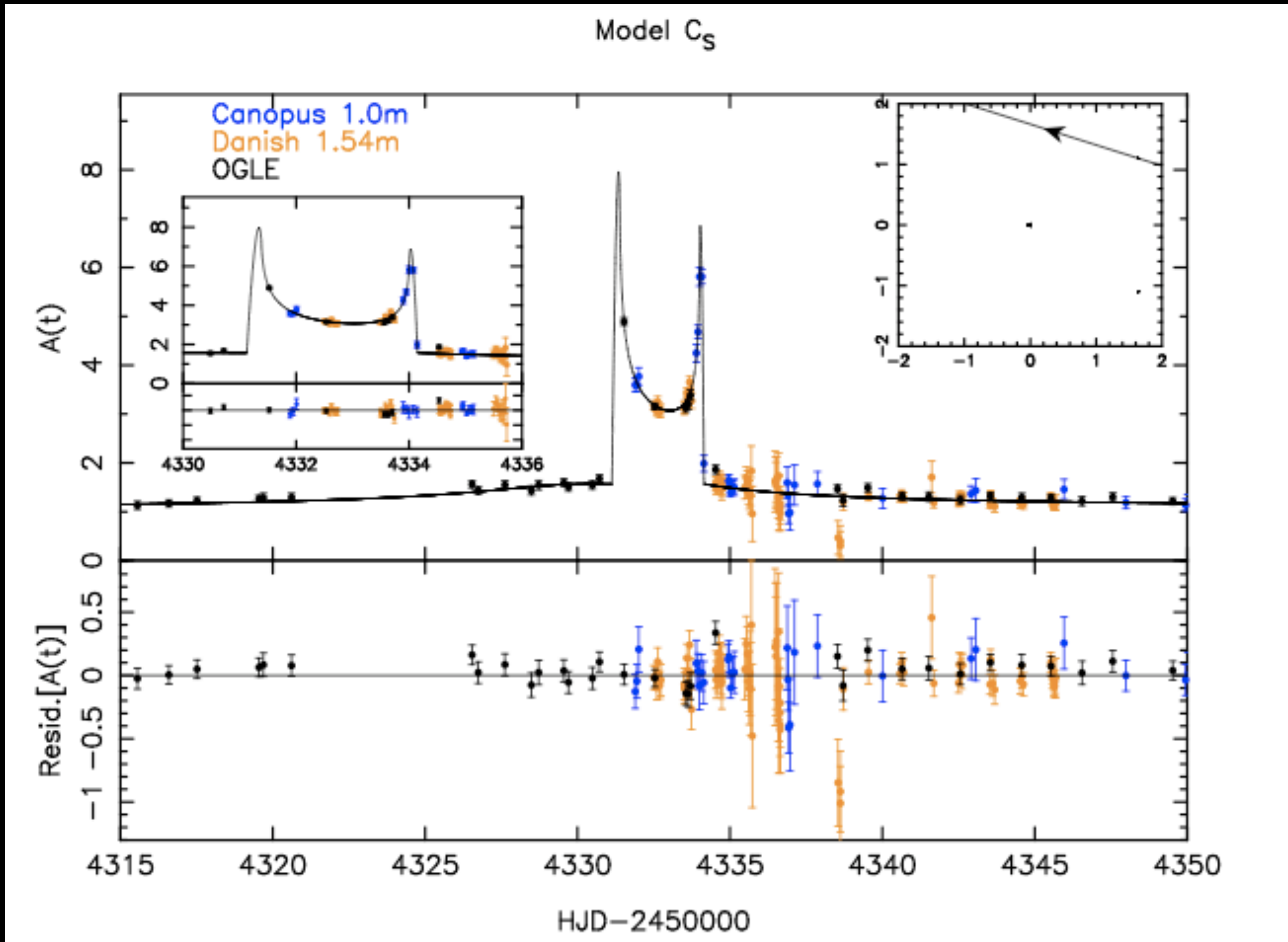
- Starting from the grid points in regions of low χ^2, we start MCMC runs with (d, q) left free
- Explore the minima regions
- This locates all the minima --> all models

Method summary

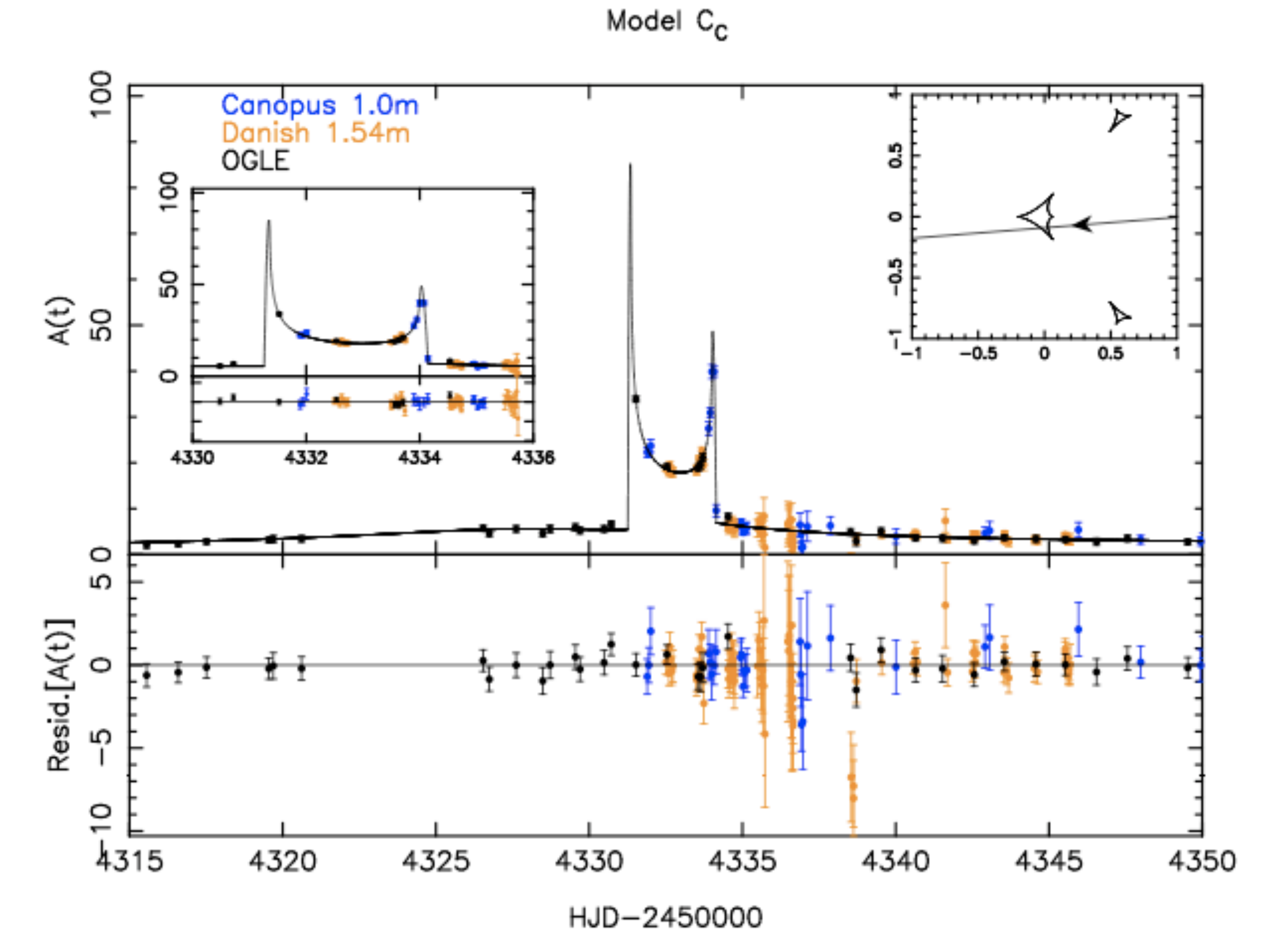
a) Build a grid using GA + alternative parameters

b) Converge each grid point using MCMC, standard parameters

c) Start MCMC from minima regions to refine χ^2 map minima



Model C_S
Canopus 1.0m
Danish 1.54m
OGLE
A(t)
Resid.[A(t)]
HJD−2450000



Model C_c
Canopus 1.0m
Danish 1.54m
OGLE
A(t)
Resid.[A(t)]
HJD−2450000

Results for OB07472

- We find minima with non-intuitive parameters that would not be found otherwise
- Small q (0.001) minimum model has t_E ~1100 days, t_0=5959 (2 February 2012!)
- We must use our knowledge of distributions of physical parameters to determine which models are favoured

Future additions?

- χ^2 is not a sufficient criterion to determine which is the best model
- Include priors on parameters from distributions of tE, luminosity function of the bulge, ...

Summary

- Advantages of this approach:
    - locates widely separated minima
    - requires minimal guesswork --> best models are not biased by initial guessed parameters
    - ensures that the parameter space is explored thoroughly and systematically
- Ground for automated binary-lens fitting