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An alternative parametrization for binary-lens caustic-crossing events

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Abstract: Microlensing has become a powerful probe of extrasolar planet populations, with a sensitivity function that complements the more established radial velocity method at wide separations. In microlensing events, detection of planets (and more generally stellar companions) relies on multi-parameter modeling of light-curve distortions relative to a point-source lensing model. This is in general a laborous and computer-intensive process, which limits the throughput of many microlensing planet searches. We describe a new parametrization of the binary-lens model with parameters that closely match the features of the light curve, rather than the lens configuration itself. This shows great promise for much faster and more automatic analysis of light curves, and thus more complete analysis of candidate events and faster reaction to on-going light curve changes.

1. Introduction

Anomalous microlensing events usually require very detailed analysis to fully characterize their nature. This applies to a class of microlensing events which display caustic crossing features in their light curves, in particular binary lenses. These events are of primary interest, because they account for around ten percent of the overall number of detected microlenses. But they are also very challenging, because a full exploration of the parameter space is required to unambiguously determine their characteristics. Brute force is not an option because the models are also computationally very demanding. A way to reduce the volume of the parameter space is then to base directly the parameters on features that appear in light curves, as e.g. Albrow et al. (1999) who proposed a parametrization to model separately an individual caustic crossing. Here (Cassan 2008) we redefine completely the basic binary-lens parametrization, so that all the models computed in the fitting process display a caustic entry and exit at the date where they are seen on the observed light curve.

2. A new parametrization

In Fig. 1, a binary lens is parametrized (thin letters) with the classical geometrical parameters u_0 and α (respectively the source trajectory closest approach to the origin and its angle with the binary lens axis), as well as t_0 (date at closest approach) and the Einstein time t_E. In the proposed alternative parameterization (bold letters in Fig. 1), the source motion is defined by the dates of caustic entry and exit, t_{entry} and t_{exit} , which occur at (vector) positions ξ_{entry} and ξ_{exit} . Since these latter points are located on the caustic, we introduce two new (one-dimensional) parameters s_{entry} and s_{exit} , which are values taken by a proper curvilinear abscissa s along the caustics, which uniquely define the entry and exit positions. The choice of this curvilinear abscissa is explained in the next section.

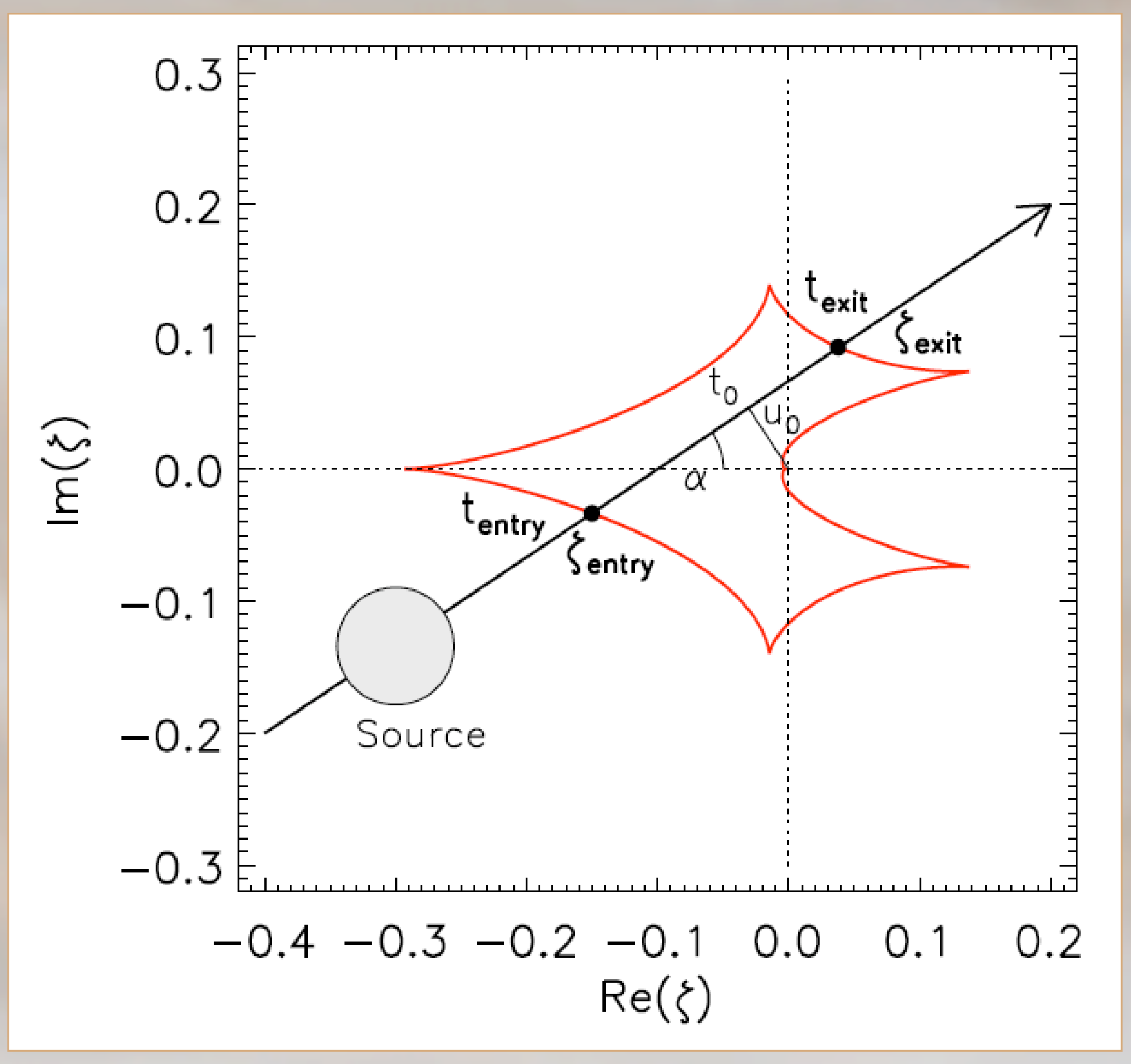

Fig. 1: Binary lens parametrizations

3. A regularly spaced curvilinear abscissa along the caustic lines

The construction of the curvilinear abscissa s is based on the equation of Witt (1990) which is already a parametrization of the caustics by a parameter ϕ. We investigate its analytical properties to build a curvilinear abscissa which has the property to be regularly spaced, monotonic, and to fully and uniquely parametrize the caustic. The two left columns of Fig. 2 show the caustic patterns in the three possible topologies: intermediate (upper pannels), wide (middle panels, central and secondary caustics) and close (central and upper secondary caustic, lower panels). In the upper panel on the left, the sampled points on the caustic are computed assuming 130 points regularly spaced in ϕ (in practice this number is much larger): most of the points accumulate near the cusps. In comparison, the next panel on the right shows the regular spacing obtained by using the constructed curvilinear abscissa s. The three plots in the right most column show the conversion function $s(\phi)$ for each of the cases, where we have chosen that a full caustic (*i.e.* one closed caustic) is fully sampled for $s \in [0,2\pi]$. The flattening that are seen on the curves correspond to the locations of the cusps.

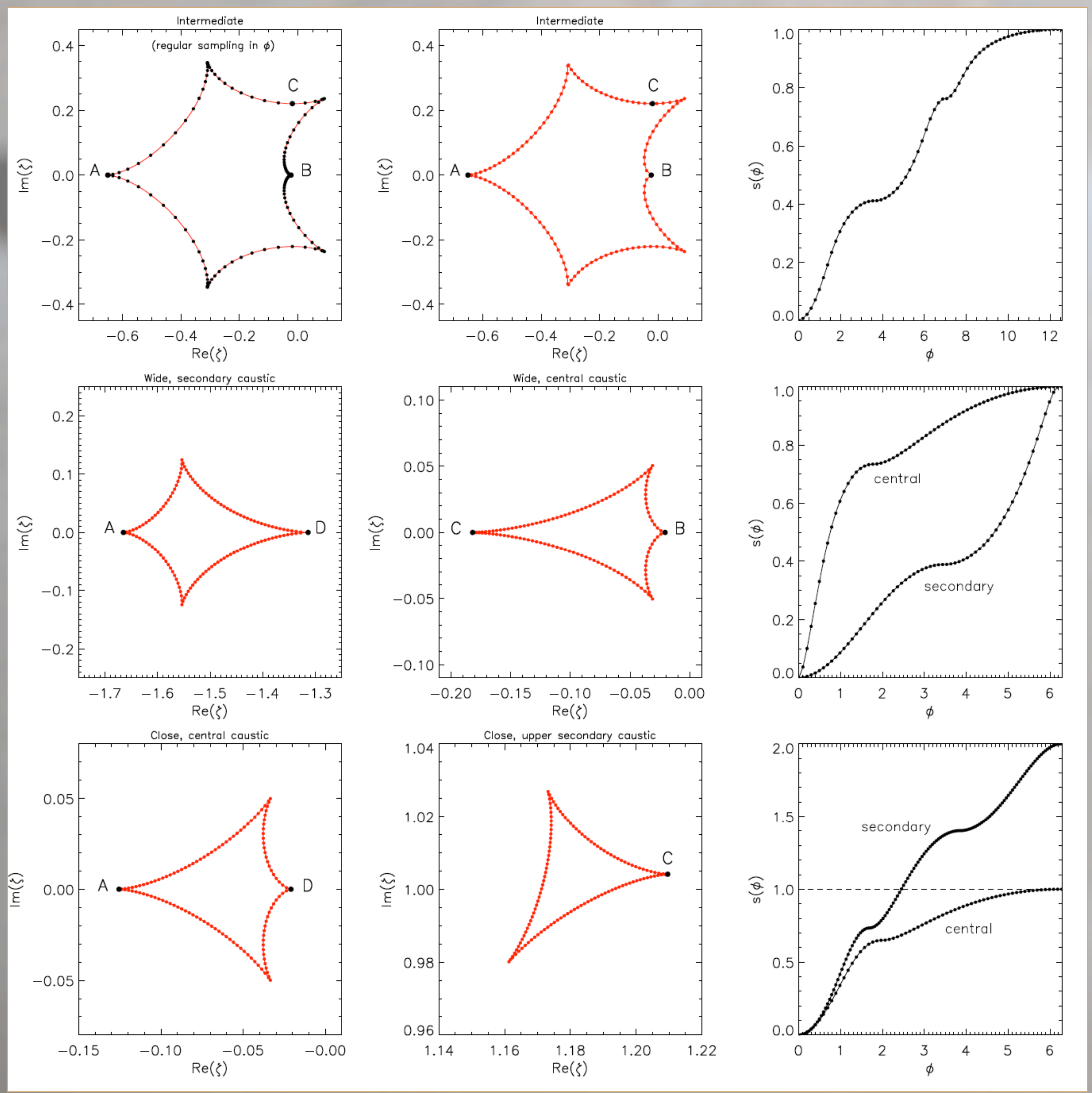

Fig. 2: Sampling of the caustics with the new curvilinear abscissa

4. Application: the binary-lens microlensing event OGLE-2007-BLG-472

The binary lens event OGLE-2007-BLG-472 (Fig. 3) is a very good example of a binary lens event which exhibits many local minima, very far from each other in the parameter space, and is thus a very test-case for the parametrization presented here. We then use this event to outline a general fitting scheme that can be efficiently used to model binary-lens events (Kains et al. 2009).

We start by exploring a wide region of the parameter space with a binary separation (d)-mass ratio (q) grid regularly sampled in logarithmic scale, and fit for the remaining model parameters. From this we build a $\chi2(d,q)$ map (Fig. 4). In order to sample efficiently and extensively s_{entry} and s_{exit} , we use a genetic algorithm, well-suited to avoid to get stuck in local minima. We finally refine the models on the (d,q) grid by performing a Markov-Chain Monte-Carlo (MCMC) fit. We then identify all the local minima regions on the $\chi2$ map, and refine the solution by including (d,q) as fitted parameters. We find that our fitting strategy locates several minima that are extremely difficult to find with a standard parametrization.

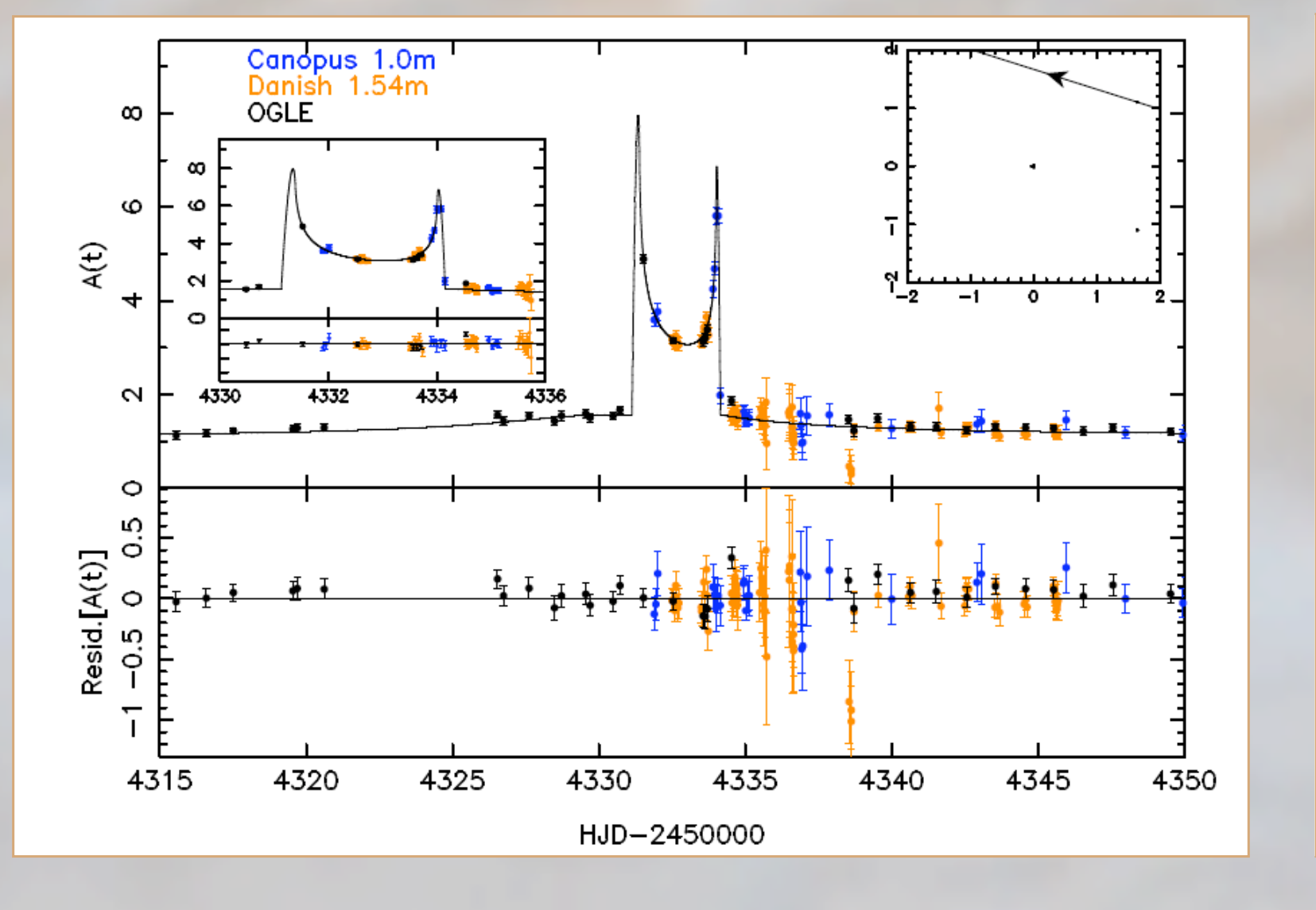

Fig. 3: OGLE-2007-BLG-472 light curve

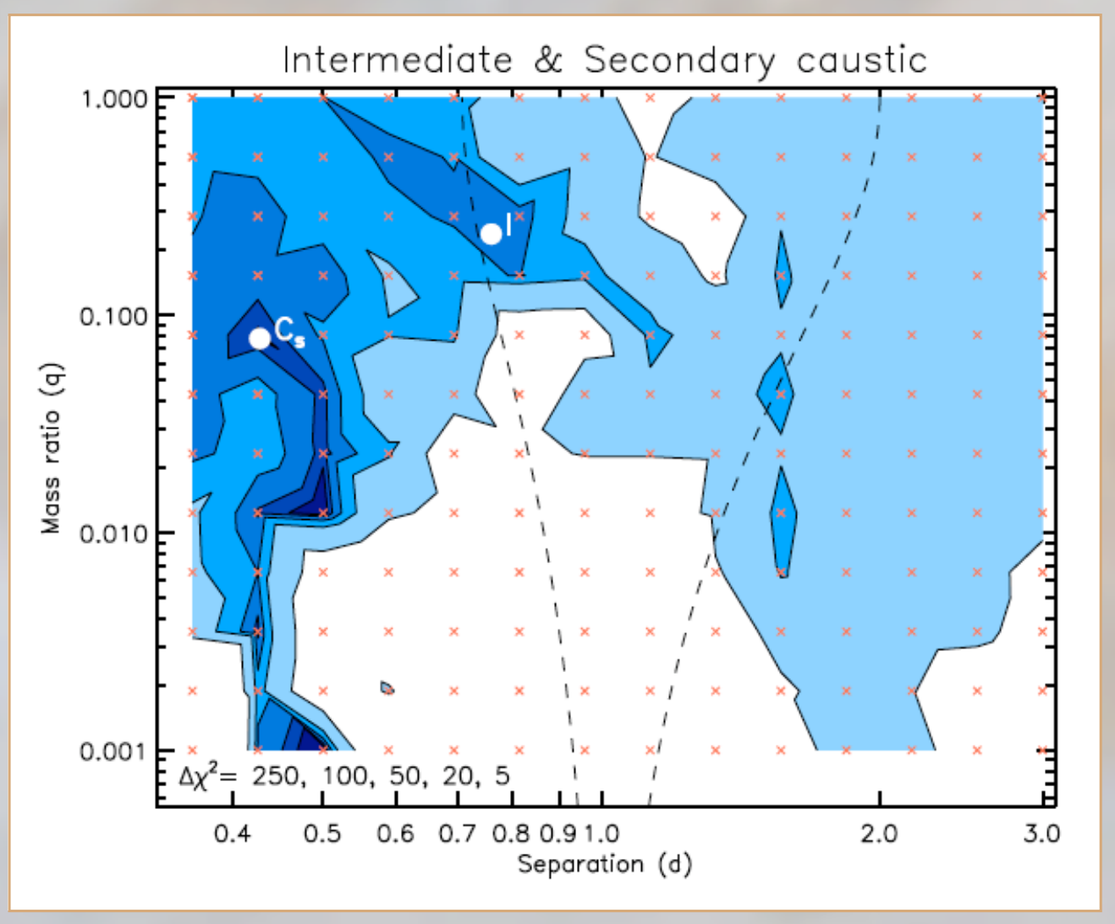

Fig. 4: One of the obtained $\chi2$ map

5. Conclusion & prospects

Current survey and follow-up networks of telescopes gather microlensing data at an accelerating rate, but every year several light curves are not modelled. One reason is the lack of automation of current modelling codes, which still require manual inputs and human expertise to be used. In this respect, the work presented here aims in providing a parametrization which is better-suited than others for automatic fitting of binary lenses. There is no doubt that new generations of automated telescopes (e.g. Tsapras et al. 2009) will also greatly benefit from such developments.

References

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