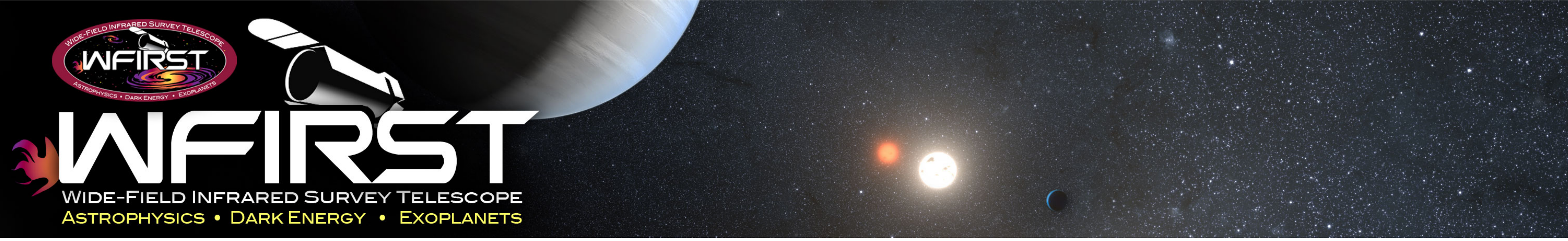

WFIRST: A Simple Approach for the Recovery of Planetary Parameters From Microlensing Light Curves

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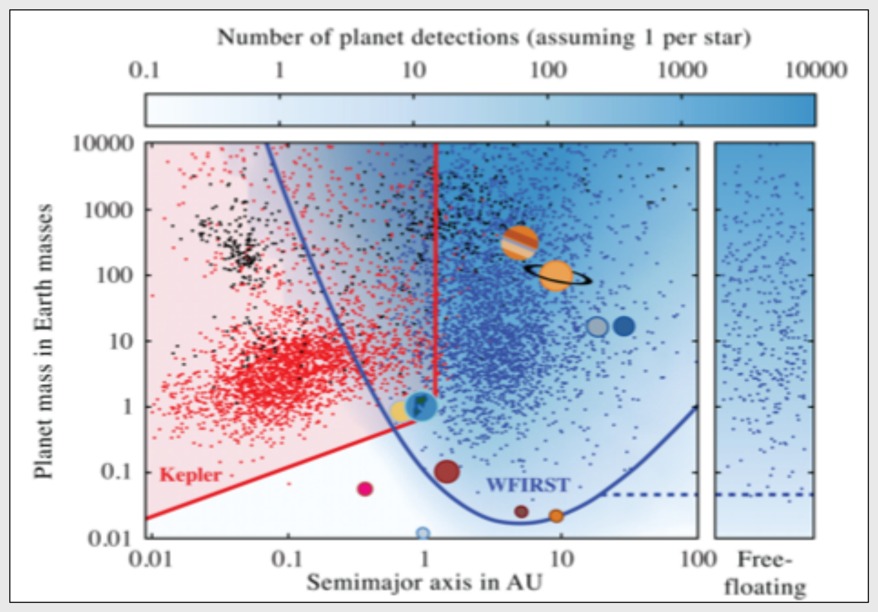
The WFIRST Mission

Kepler has been playing a leading role in the field of exoplanets for years, but is only sensitive to planets relatively close to their host star. WFIRST, using the microlensing technique, will be complementary to Kepler, and is expected to detect over 1000 planets with a wide range of masses at wide orbits. This will be a big step towards addressing issues of planetary formation and evolution.

WFIRST will find ~3000 microlensing events in each of its 72-day seasons, compared to the current rate of ~2000 microlensing events now discovered each year.



Fitting a Heuristic Model to Planetary Microlensing Events

- Traditional methods for detecting lens systems with planets and determining the full set of system parameters require a great deal of time and individual effort.
- We have created a fully automated algorithm to process large numbers of microlensing light curves. This method is very fast compared to full binary lens calculations since it uses an analytic functional form to fit the light curves.
- We fit a standard microlensing profile (Point Source Point Lens) plus a Gaussian function to the data. The fit gives us the heuristic parameters ($t_0, u_0, t_E, t_p, t_{E,p}$, amplitude) as results.
- Finally, we convert heuristic parameters to physical parameters s (projected separation of the planet and star) and q (mass ratio between the planet and the star).

Fit a PSPL (t_0, u_0, t_E) + Gaussian ($t_p, t_{E,p}$, amplitude) → Final Parameters (t_p, u_0, t_0, t_E, t_{Ep}, amplitude) →

$$q = \left(\frac{t_{Ep}}{t_E}\right)^2$$

$$s \simeq \frac{|t_0 - t_p|}{t_E}$$

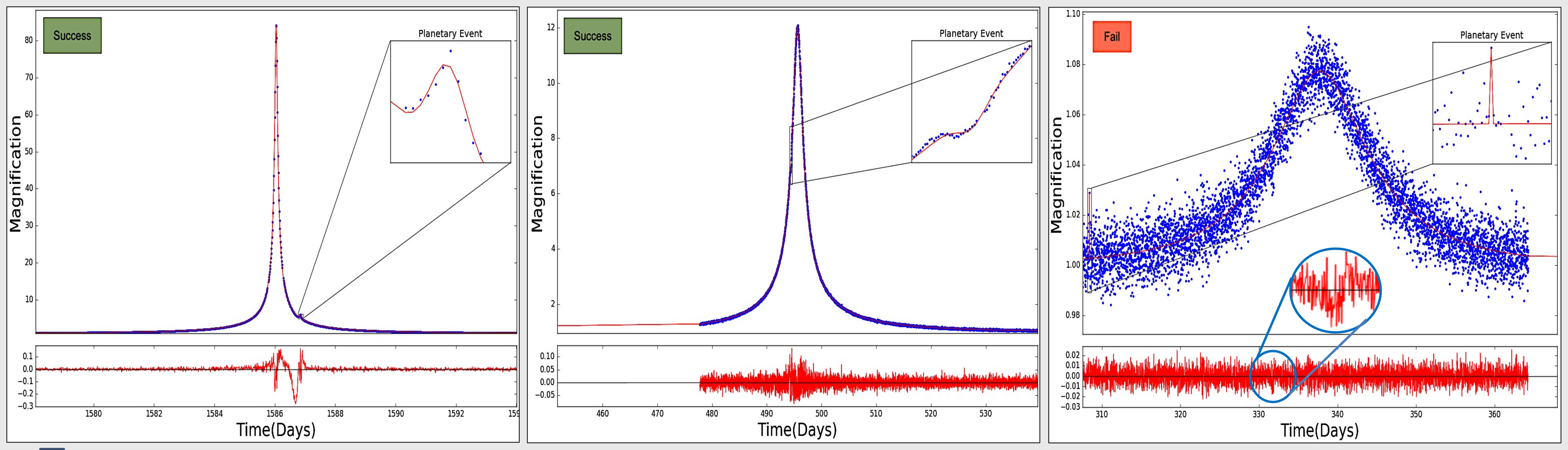
Successes and Failures of the Heuristic Model

- We calculated planetary parameters s and q for 7,000 light curves.
- Examples of two successful fits and a failed fit are shown on the upper right. Below, we have plotted the fitted parameters versus true (input) parameters to see how successful the algorithm is.
- For microlensing binary-lens events, where the mass ratio is smaller than 10^{-4} (~ Earth-mass planets), we see the parameter s is recovered very well, while for larger mass ratios, the recovery precision was poor.
- The algorithm recovers q to within better than an order of magnitude for systems with separations significantly smaller or larger than the Einstein Radius of the lens star.
- We are therefore more successful at recovering events with wide and close caustic topologies, and when the caustics are smaller.

Results and Future Steps

- The method allows an automated quick search of the entire microlensing data set for the lowest mass planets.
- Planetary parameters of this algorithm can be used as initial parameters for full analyses.
- We will explore the use of machine learning to improve accuracy.

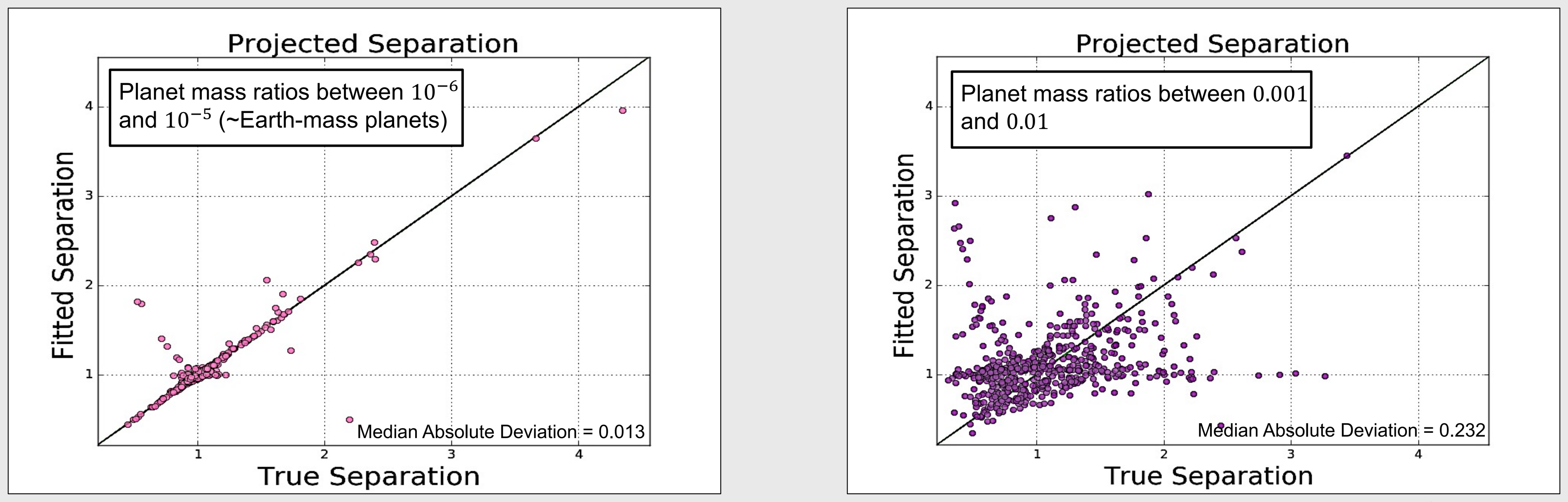
Successful and Failed Heuristic Models of WFIRST Light curves



Heuristic Model Parameters versus True Parameters → True Parameters $s = 0.93$, $q = 4.46 \times 10^{-6}$ → Heuristic Model Parameters $s = 0.93$, $q = 2 \times 10^{-5}$

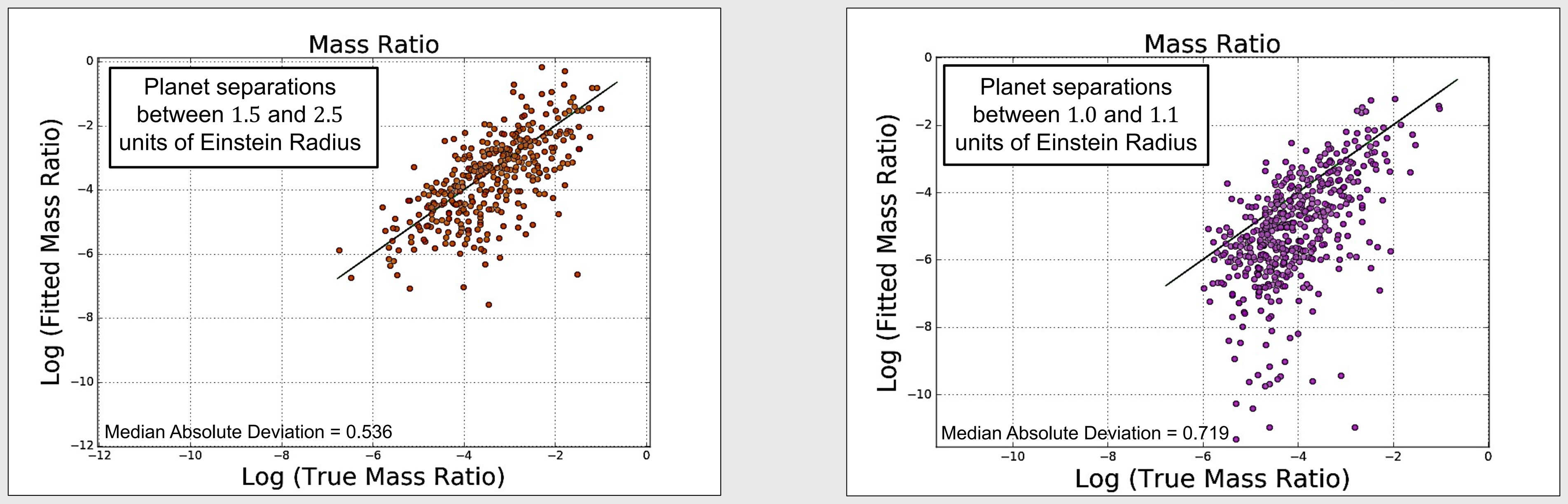
Left and Middle: Successful fits from the algorithm. The planetary perturbation in each case is well-described by a Gaussian curve. **Right**: A failed fit, where the algorithm cannot find the perturbation successfully because it is smaller than the noise in the data. The zoomed part on the residuals shows the planetary perturbation that has not been detected by the algorithm. **Bottom:** An example of Heuristic model parameters and the true parameters for a successfully fitted light curve.

Heuristic Approximation versus True Value for Projected Separation (s)



Left : A plot of fitted projected separation (s) against the true projected separation, for mass ratios of 10^{-6} to 10^{-5}. In this range of mass ratio we are very successfully recovering s with small errors. **Right:** Same plot for mass ratios of 0.001 to 0.01. At this range of q, there is a lot of scatter.

Heuristic Approximation versus True Value for Mass Ratio (q)



Left : A plot of fitted mass ratio (q) against the true mass ratio, for projected separation of 1.5 to 2.5. In this range of projected separation, we are generally recovering q to within better than an order of magnitude. **Right:** Same plot for projected separation of 1 to 1.1. At this range of s, there is a lot of scatter.