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Identifying Microlenses in Large, Non-Uniformly Sampled Surveys

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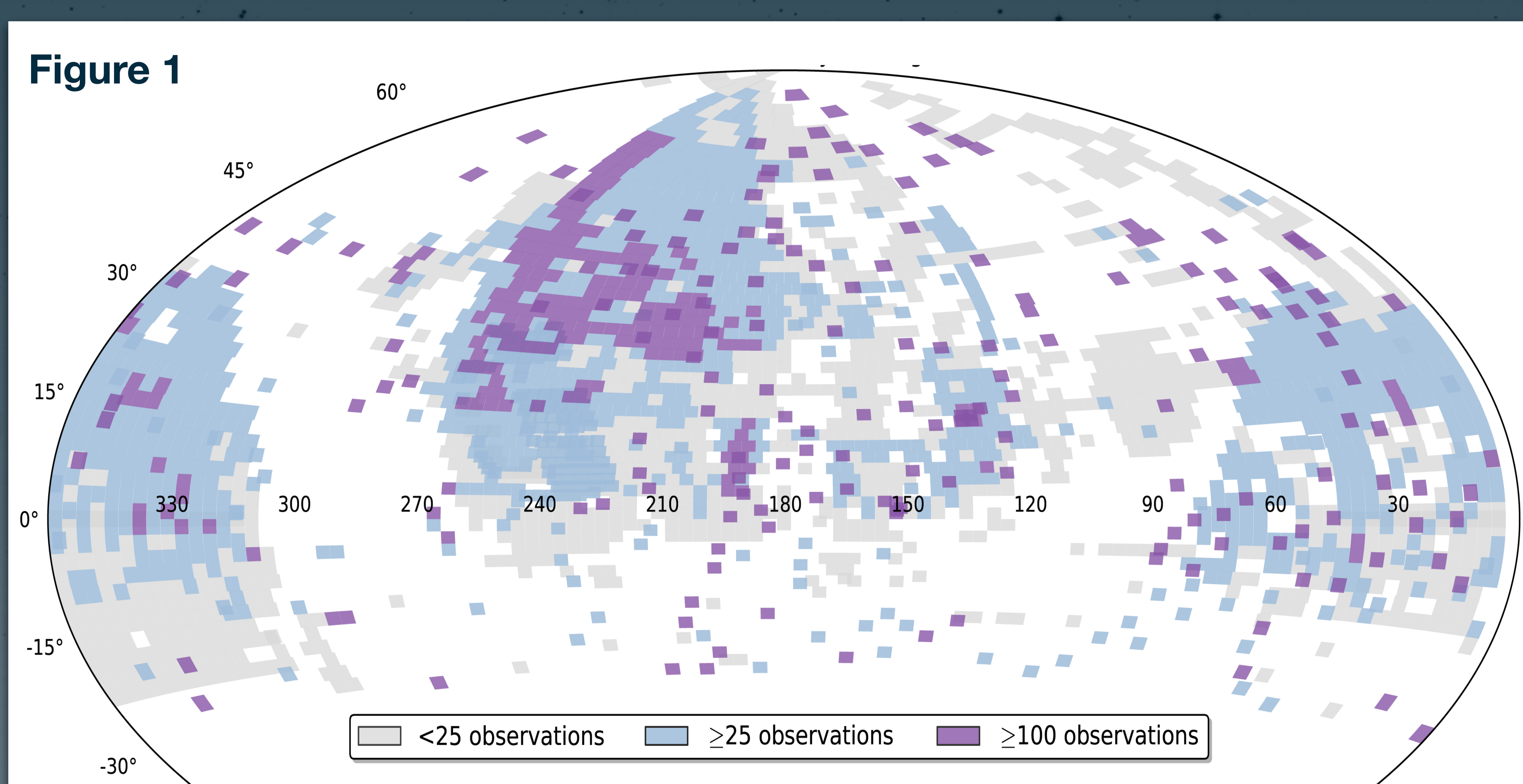
The number of observed microlensing events will increase as the next generation of photometric, time-domain surveys comes online.

Using the Palomar Transient Factory (PTF) archive, we have developed a new method for searching for such events in large, non-uniformly sampled data.

We find that η outperforms standard matched filtering ($\Delta\chi^2$) in detecting simulated events and use it to identify nine candidate events from 10^9 light curves.

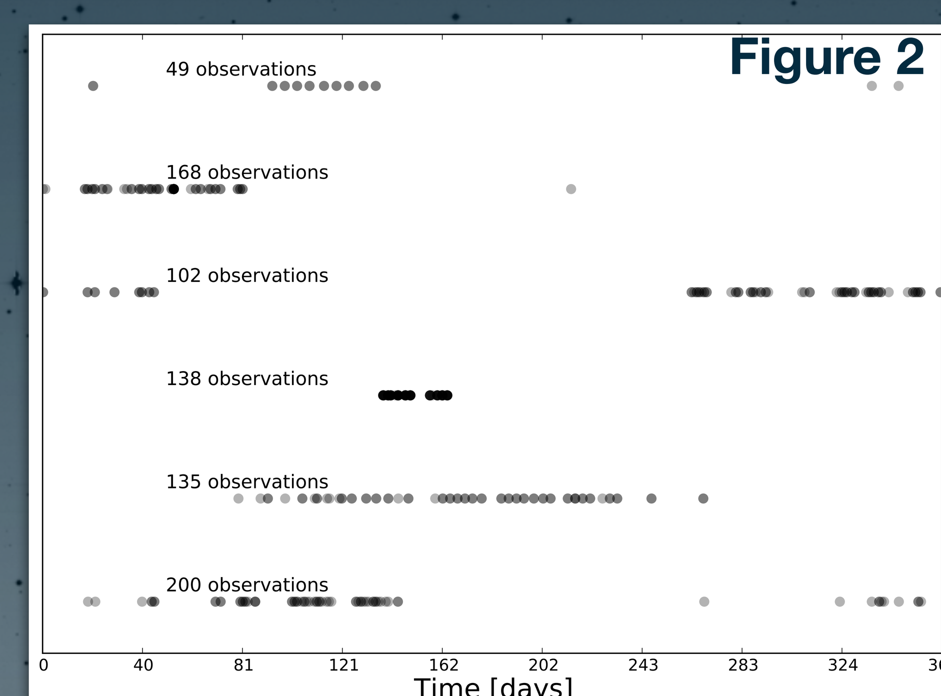
1 Will wide-field surveys aid microlens discovery?

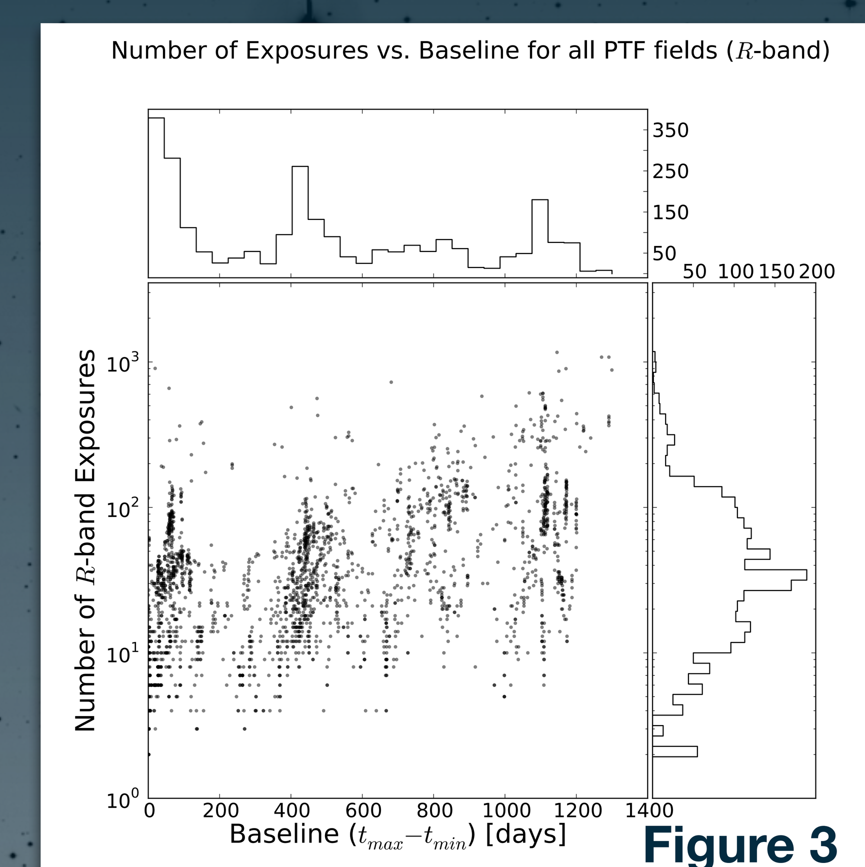
- Microlensing is used to discover exoplanets, infer Galactic structure, and search for compact stellar remnants.
- Microlensing surveys usually use high-cadence observations of dense stellar fields.
- However, wide-field synoptic surveys such as PTF often avoid dense regions to prevent e.g., blending (Figure 1).
- The event rate away from the Bulge is not well-constrained, but such events are potentially extremely interesting ().
- We have developed a new method for searching for microlensing events in large, non-uniformly sampled data sets.
- We apply this method to the PTF data and identify 9 candidate microlensing events.



2 PTF survey

- The PTF database contains ~10^9 light curves with >10 *R*-band observations.
- These light curves have non-uniform sampling: Figure 2 shows six different PTF fields observed over one year. Darker points indicate that more exposures were taken that night; the total number of observations for each field is indicated.
- A typical PTF field has ~30 exposures, but the exposure distribution has a significant tail to larger numbers (Figure 2).
- The distribution of baselines shows more structure, with peaks around ~10 days, 1 year, and 3 years (Figure 3).



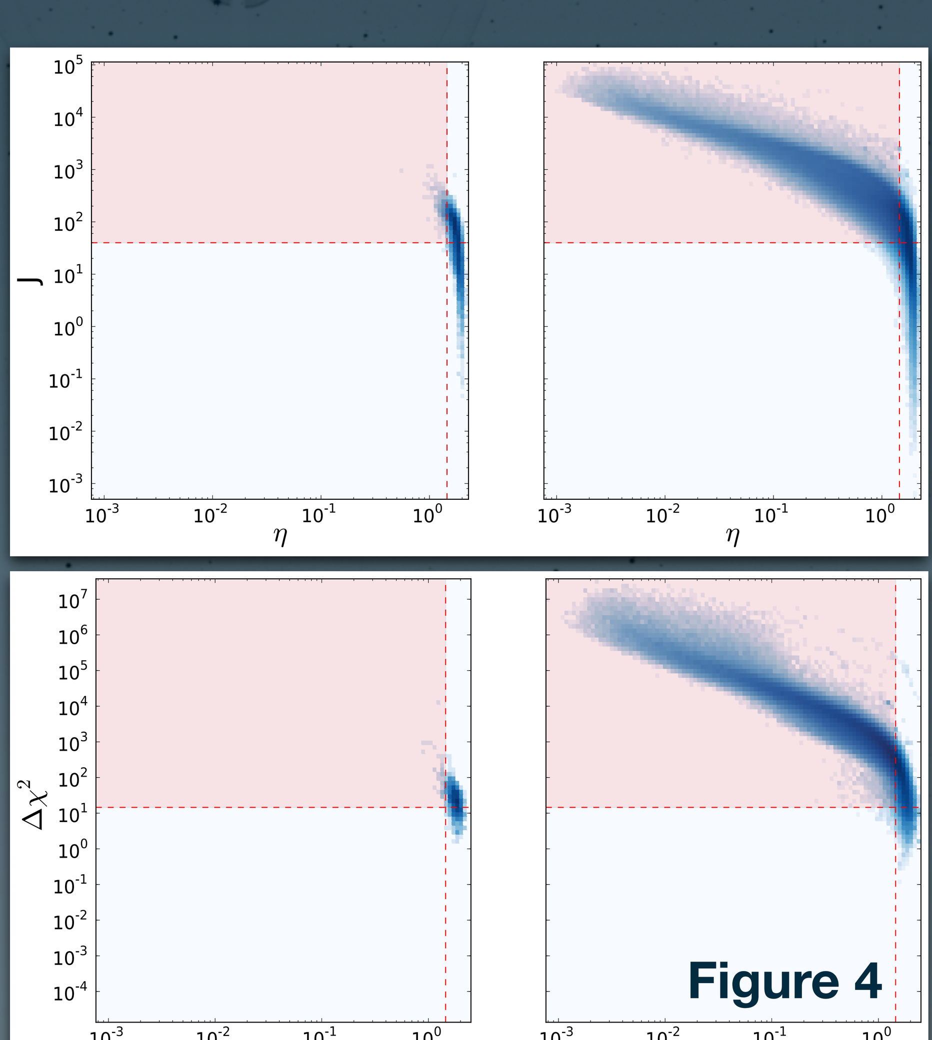


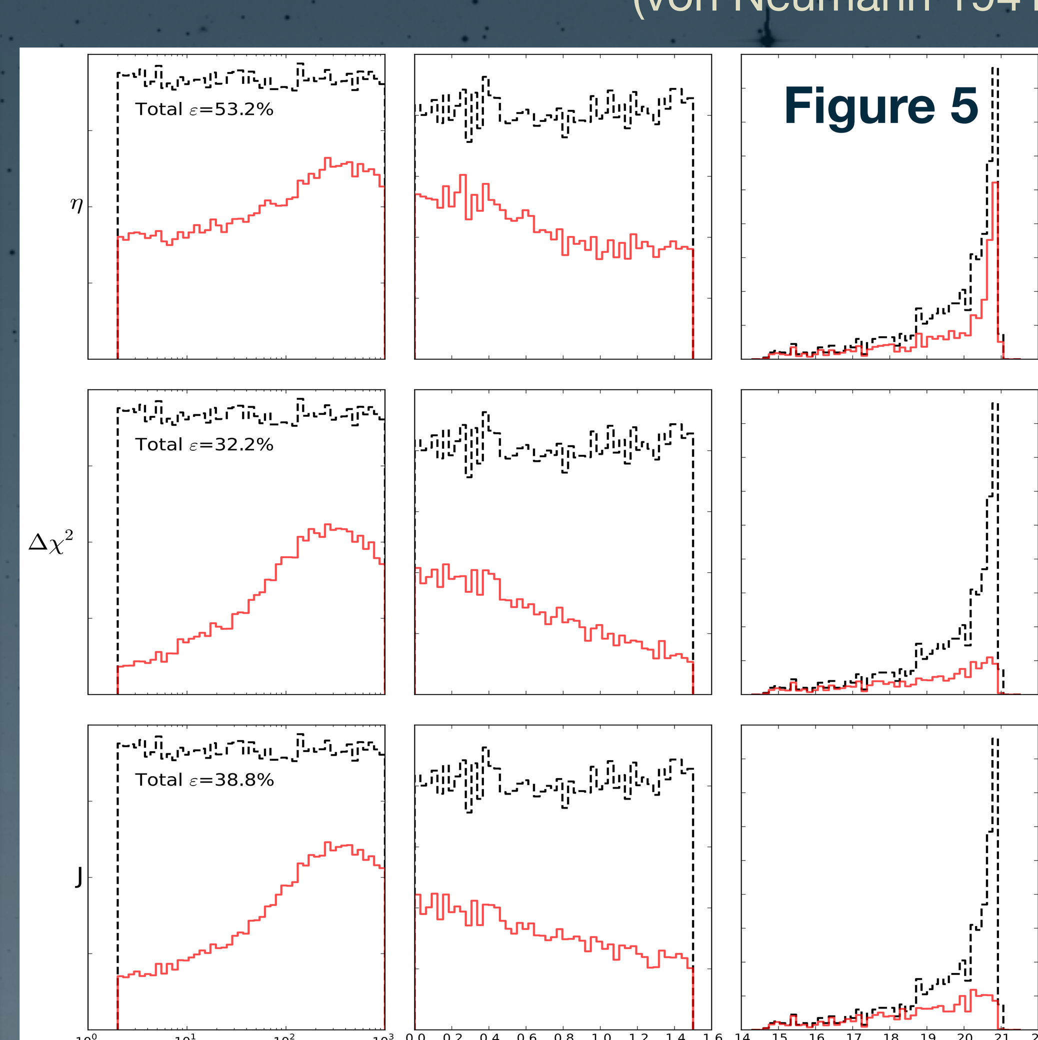
3 Finding microlensing events

- Microlensing searches often require that consecutive data points be brighter than a few times the scatter in the data.
- This is not appropriate for non-uniformly sampled data, but a brute-force model-fitting method will not work for LSST-scale surveys.
- We test a set of variability indices on simulated PTF light curves, setting selection boundaries such that 1% of simulated light curves are recovered.
- Figure 4 shows selection boundaries (red lines / regions) for three indices and distributions of light curves without (left) and with (right) simulated microlensing events.
- Figure 5 shows the detection efficiency curves for the best three indices on PTF field 4327. η, the Von Neumann ratio, outperforms standard matched filtering ($\Delta\chi^2$) and the Stetson J index.

$$\eta = \frac{\sum_{n=1}^{N-1} (M_{R,n+1} - M_{R,n})^2/(N-1)}{\sigma_R^2}$$

(von Neumann 1941)





4 Candidates

- Our procedure identifies 2377 candidates from among the initial ~10^9 light curves. These are fed to SDSS and SIMBAD to identify and remove extragalactic objects.
- Each remaining candidate is hand-vetted and passed to an MCMC model-fitting algorithm.
- Figure 6 shows nine candidate events that passed visual inspection with microlensing models overlaid (sampled using MCMC).
- We are cross-matching these sources to existing catalogs and requesting spectroscopic follow-up from PTF to determine their nature.