Gravitational microlensing in the Galactic plane

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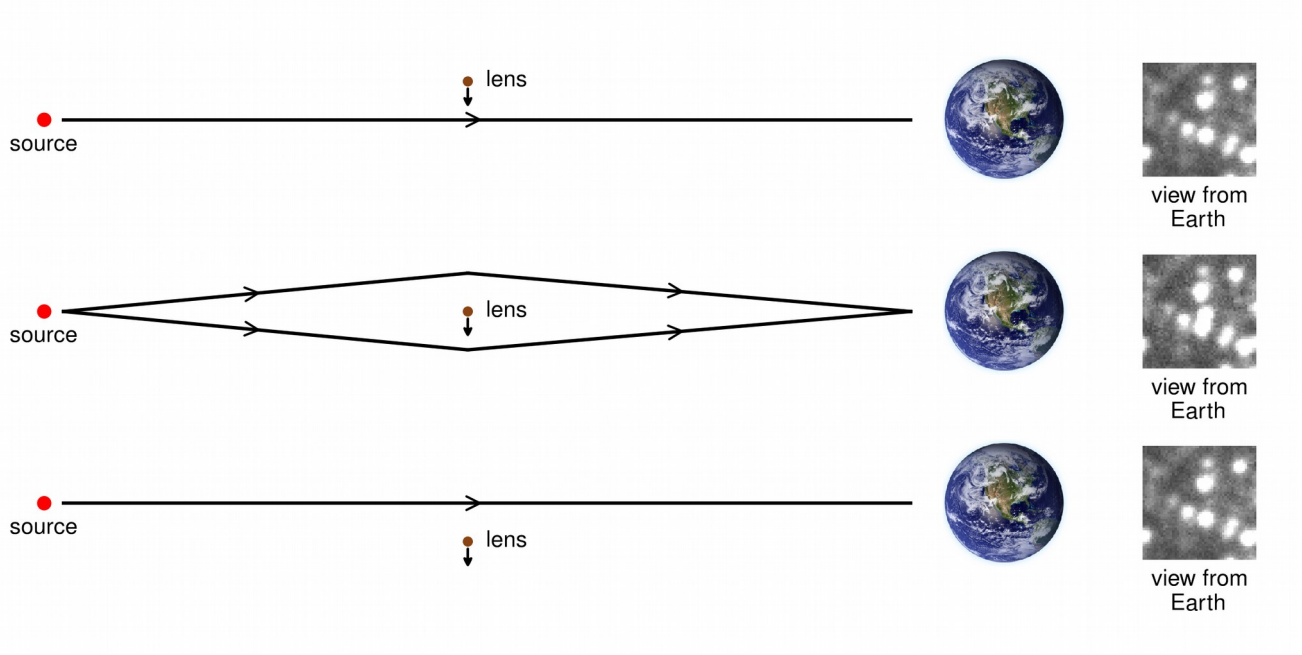
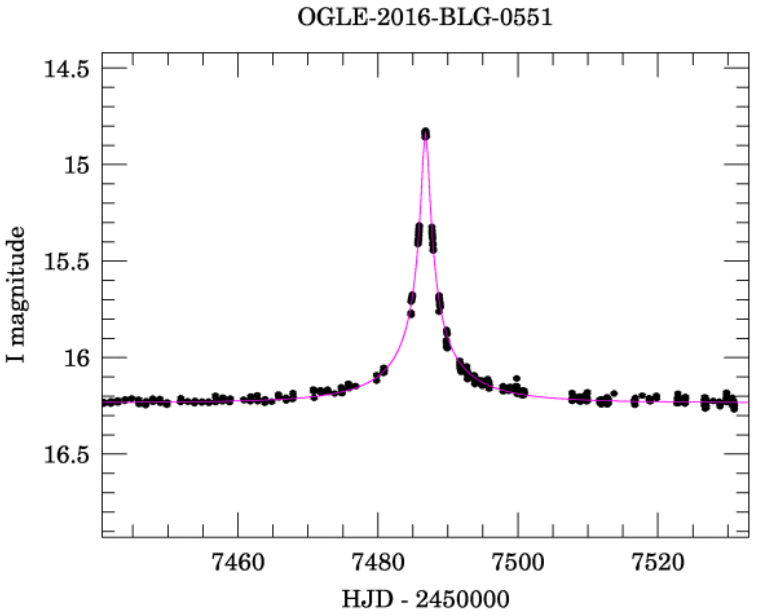
Gravitational microlensing





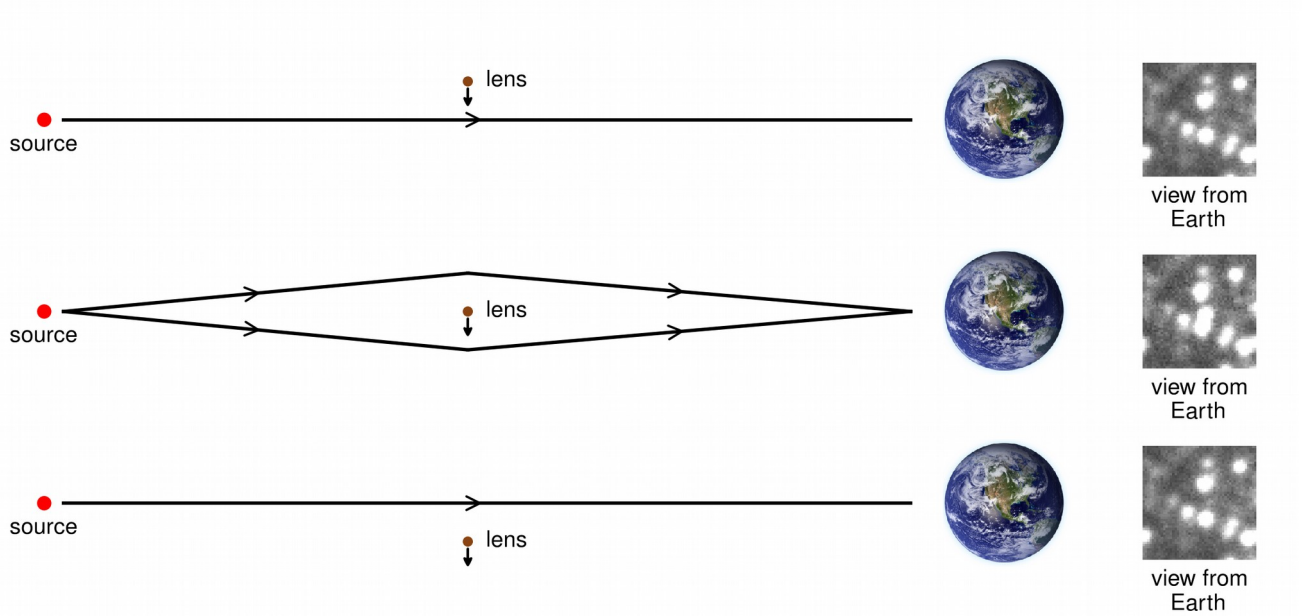
Microlensing allows one to find all types of dark objects, including single and binary black holes.

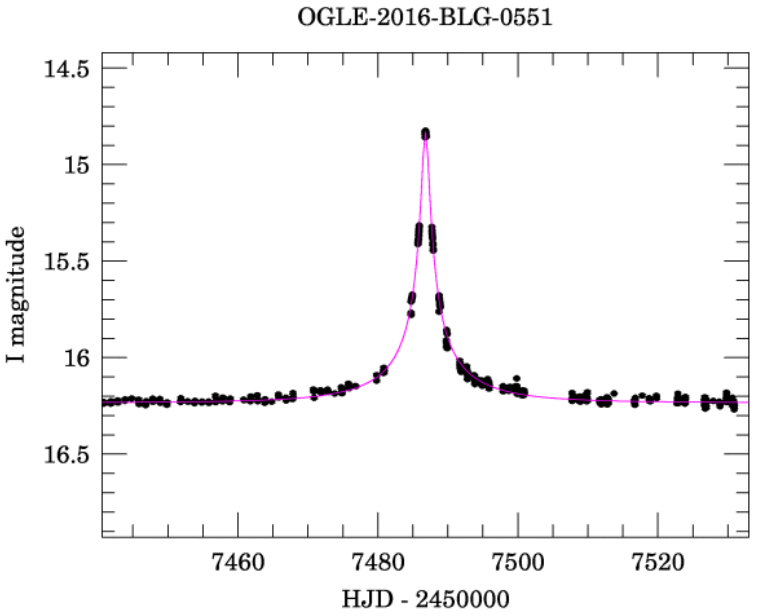
Timescales of microlensing events depend on the lens mass

$$t_E \sim M^{1/2}$$

(BH events are long, $t_E \gtrsim 100$ days)

Gravitational microlensing

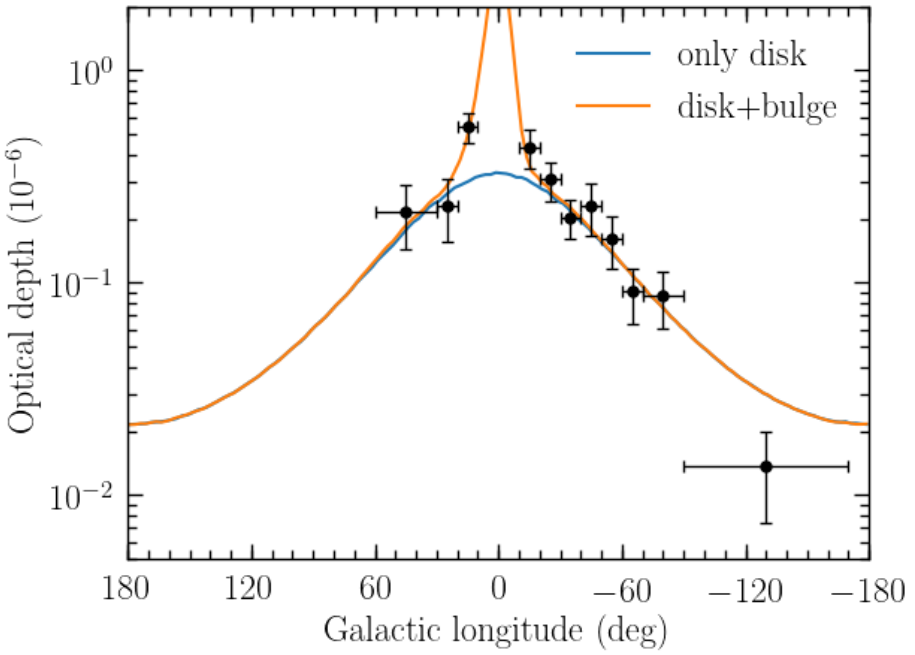




Gravitational microlensing surveys (OGLE, KMTNet, MOA) are traditionally observing the Galactic center, where the probability of microlensing (and the event rate) is the highest.

Microlensing in the Galactic plane

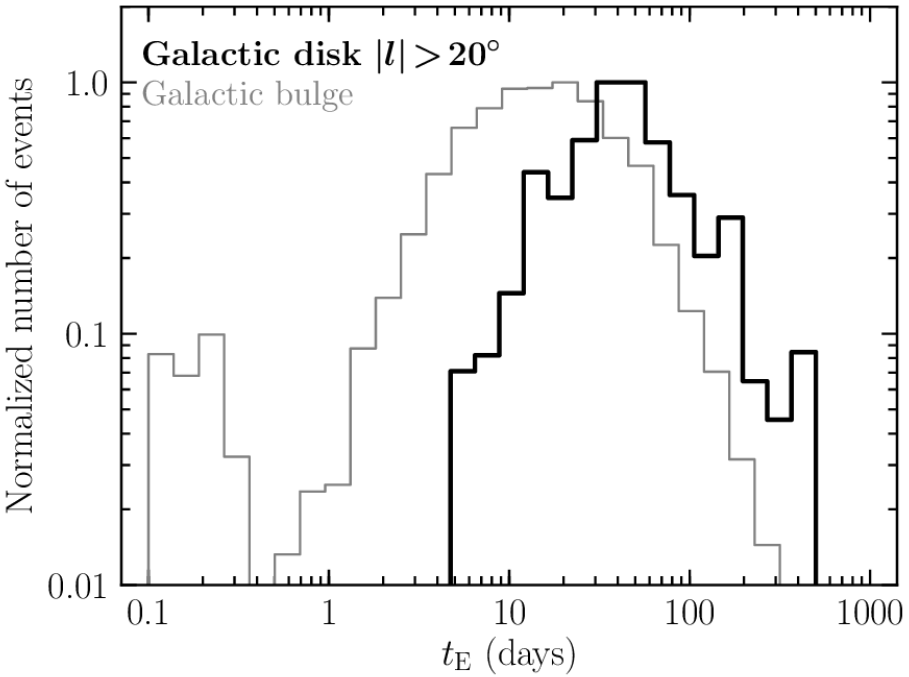
- optical depth to microlensing and event rates are an order of magnitude smaller than in the Galactic bulge
- the entire Galactic plane (over 4000 sq.deg.) must be observed with a high cadence (2-3 days)



Mróz et al. 2020a

Microlensing in the Galactic plane

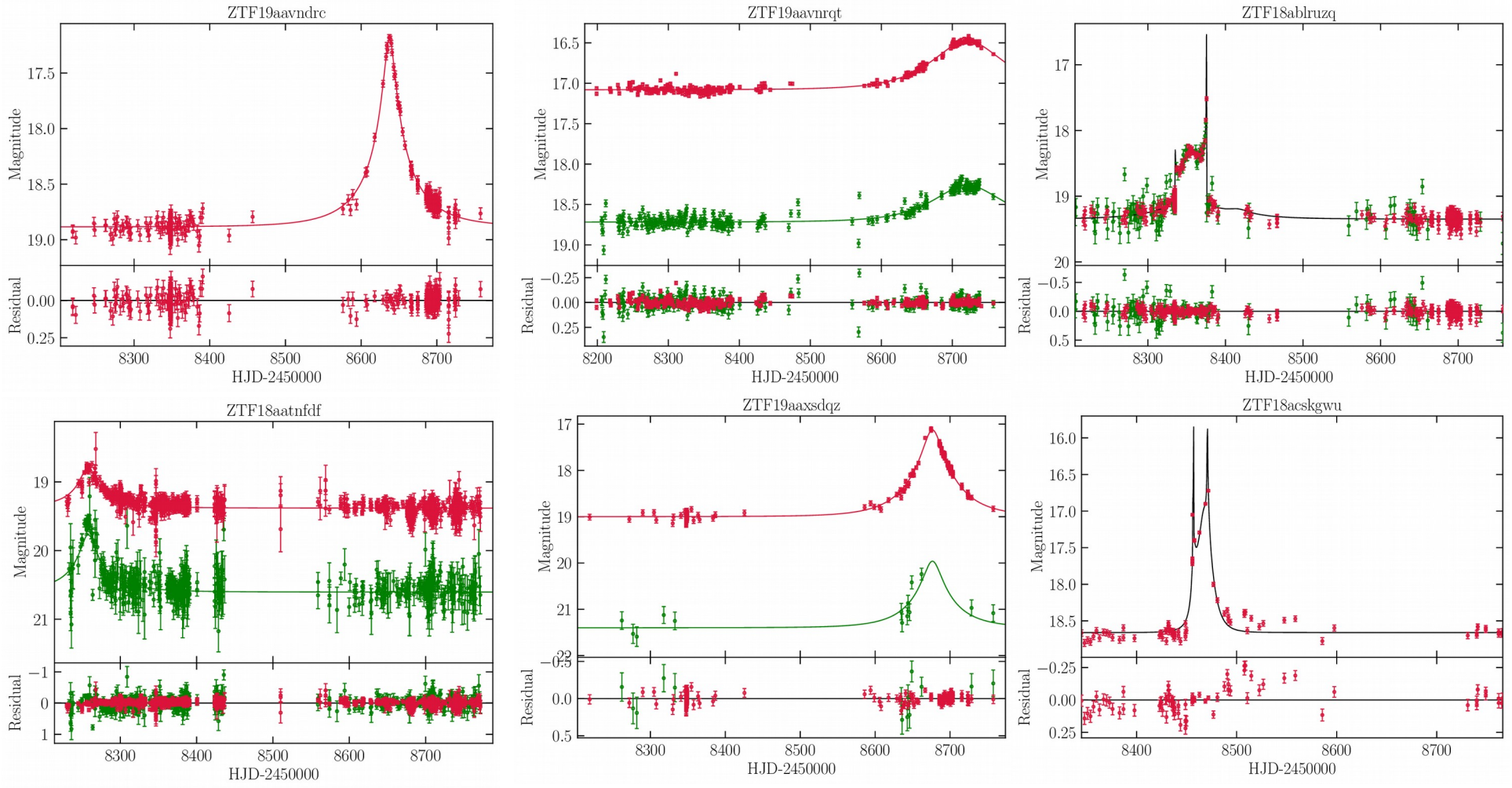
- microlensing events in the Galactic plane have longer timescales and larger Einstein radii than those in the Galactic bulge
- lens mass measurements become easier to obtain than for a typical Galactic bulge event



Einstein timescales

Mróz et al. 2017
Mróz et al. 2020a

ZTF microlensing events



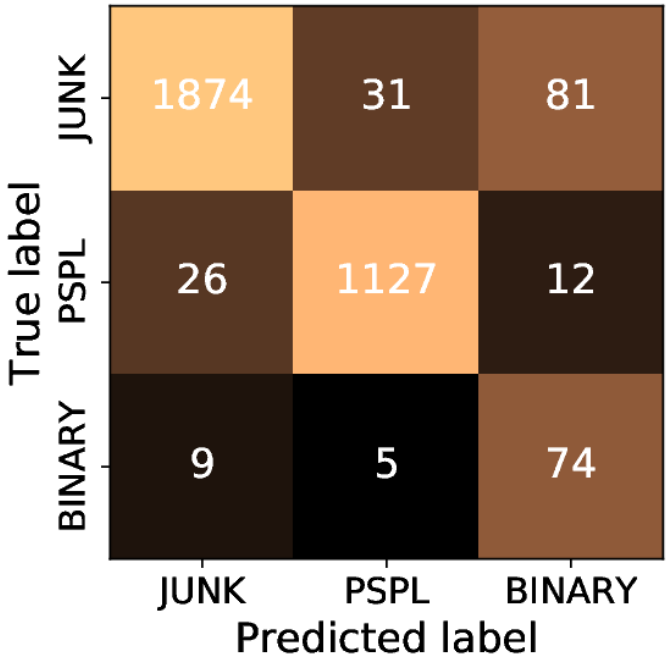
Mróz et al. 2020b: 30 microlensing events in the ZTF DR2 data

Machine-learning identification of microlensing events

- Neural-network-based classifiers
- Trained on OGLE data
- Two classifiers: for single- and binary-lens events
- Classifiers can correctly recognize ~98% of single-lens events and ~80-85% of binary-lens events

dataset	accuracy	precision	recall
validation set	0.980	0.962	0.981
test set	0.977	0.962	0.975

Table 1. Performance of the PSPL classifier on the validation and test sets.



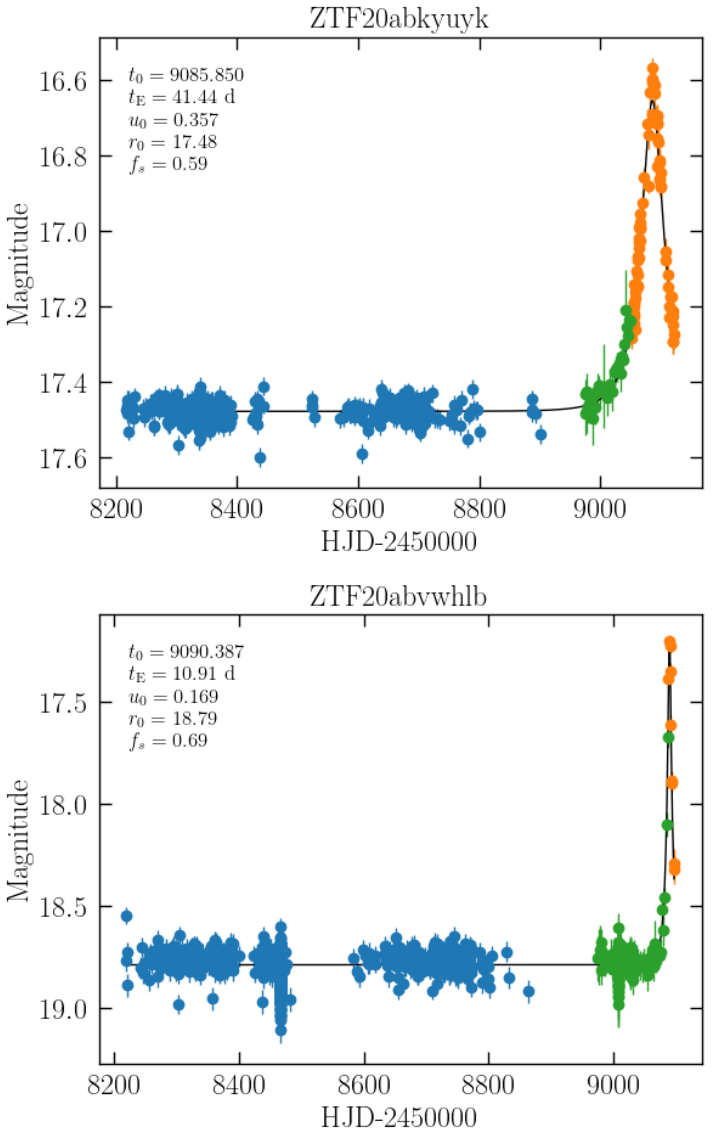
Mróz et al. 2020c

Machine-learning identification of microlensing events

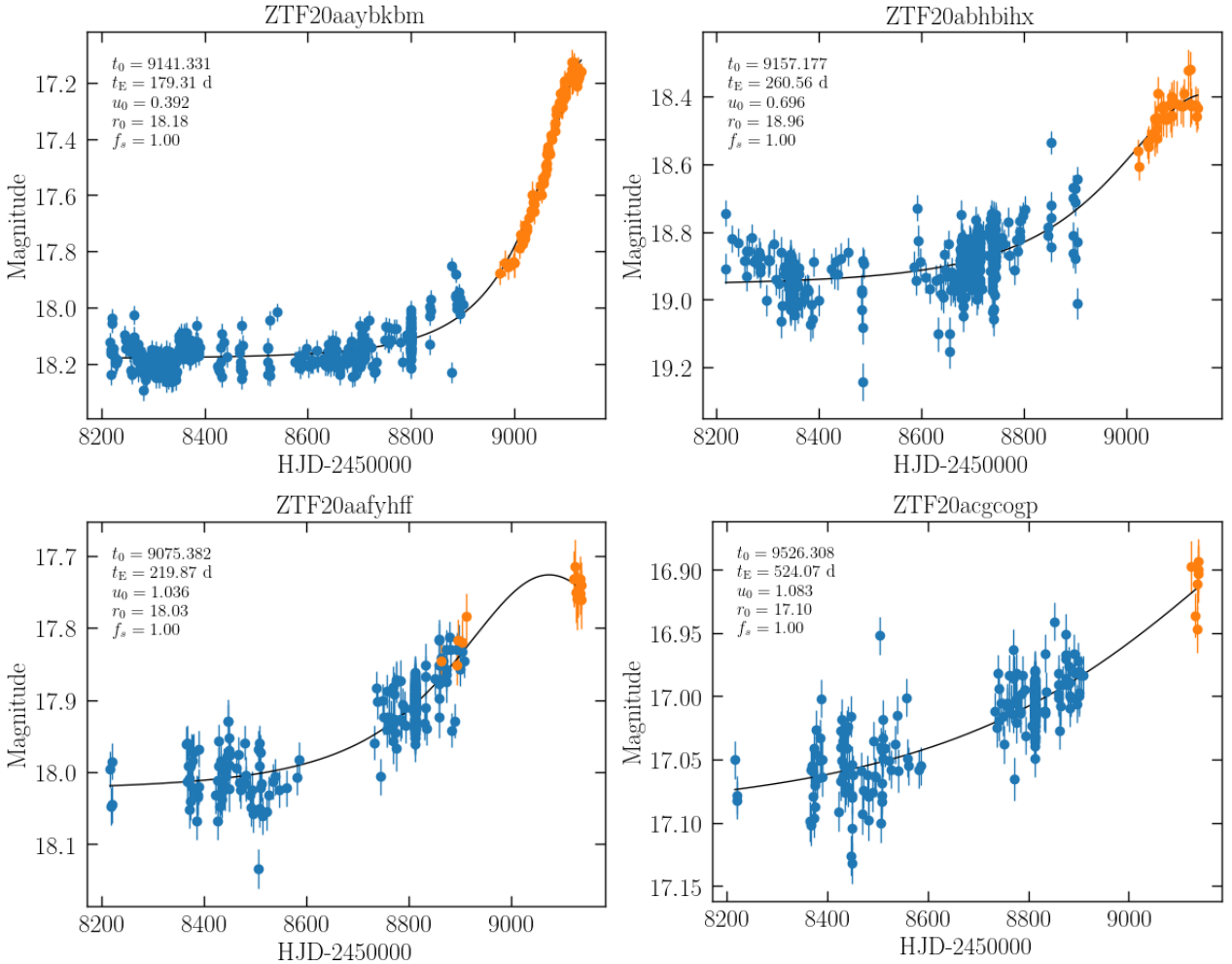
- I run the classifiers on all ZTF DR3 data (that is, ZTF alerts with a stellar counterpart on the reference image)
- Found additional 12 events from late 2019

Finding microlensing events in real-time

- I wrote a filter for finding microlenses in the ZTF alert stream in real-time
- ~ 1 candidate / week
- Events are spectroscopically and photometrically followed-up as part of the LCO Key Project OMEGA



Very long-timescale events



Summary

- High-cadence (2-3-day cadence) observations of the Galactic plane by ZTF are necessary to detect microlensing events
- Ongoing microlensing events are detected in real-time and followed-up by LCO
- Work in progress: search for long-timescale events

Gravitational microlensing

- Microlensing allows one to find all types of dark objects, including single and binary black holes
- Timescales of microlensing events depend on the lens mass

  $t_E \sim M^{1/2}$

  (BH events are long, $t_E \gtrsim 100$ days)

- Lens mass:

$$M = \frac{\theta_E}{\kappa \pi_E}$$

- π_E - microlens parallax (can be measured from the light curve)
- θ_E - angular Einstein radius (can be measured by *Gaia* – all ZTF microlensing events are concurrently observed by *Gaia*)