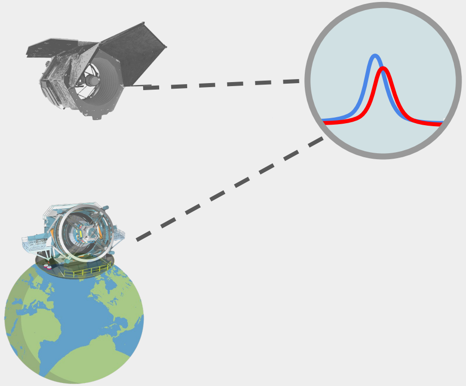
Assessing the combination of Vera Rubin and Nancy Roman observatories for enhanced characterization of microlensing planetary events

*Work partially supported by **Kickstarter project**: Getting started on Transients and Variable Stars for Rubin's LSST in Argentina*



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Anibal Varela, for the TVS Microlensing sub-group

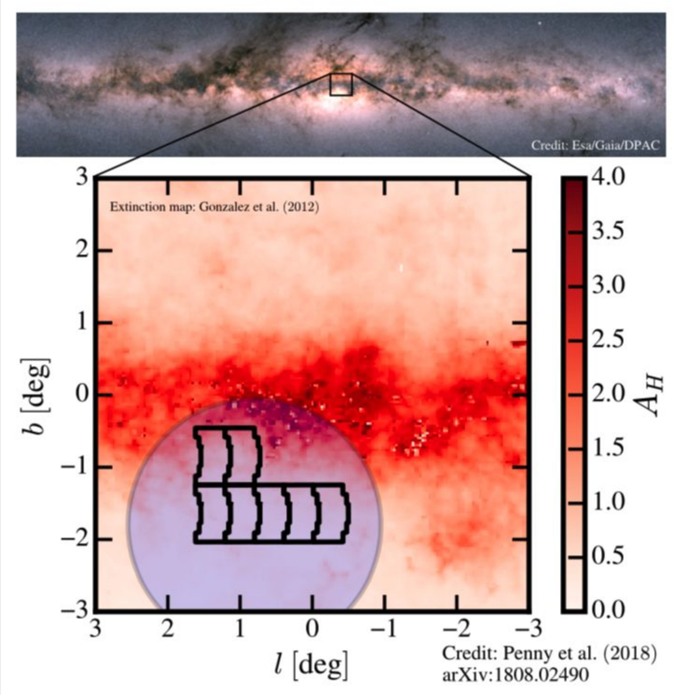
Motivation

The Roman mission will carry out an exoplanet survey

- Galactic Bulge Time Domain Survey, covering ~2 sq-deg
- Expects to detect thousands of exoplanets through microlensing
- High cadence (imaging every ~15 min) ~ 2 month seasons, but with large gaps
- Will be launched in 2027

Rubin data will also be important for microlensing

- TVS microlensing subgroup (see report by Somayeh Khakpash)
- The Rubin footprint includes the Roman fields
- Starts science operations in 2024, for ten years
- Improve the detection and characterization of microlensing events:
  - Provide precursor data for Roman, longer time scale for baseline
  - Able to fill-in some gaps of the Roman data
  - Enable microlensing parallax to be measured for some events



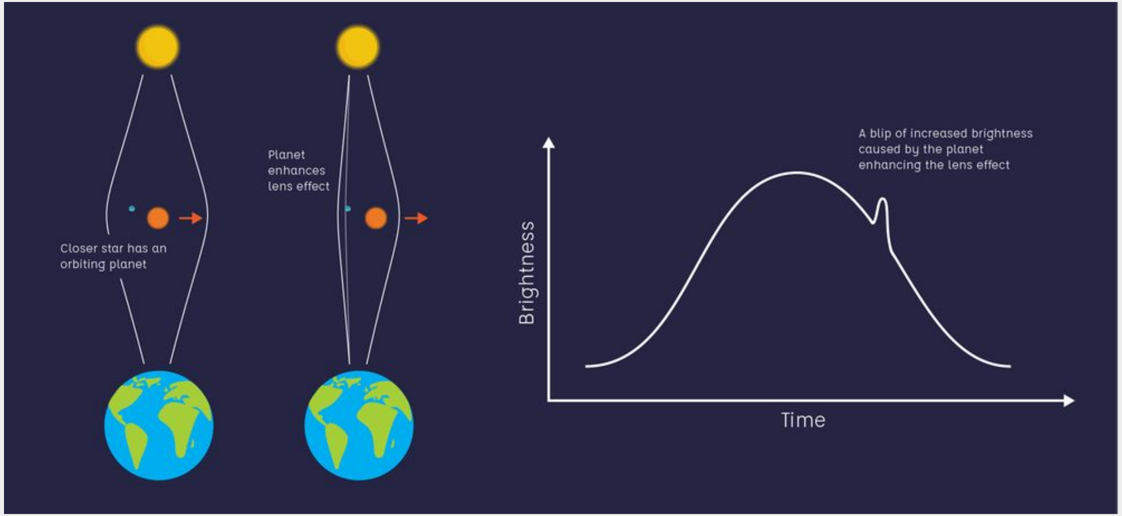
Maximizing science return by coordinating the survey strategies of Roman with Rubin, and other major facilities [arXiv: 2306.13792]

Microlensing

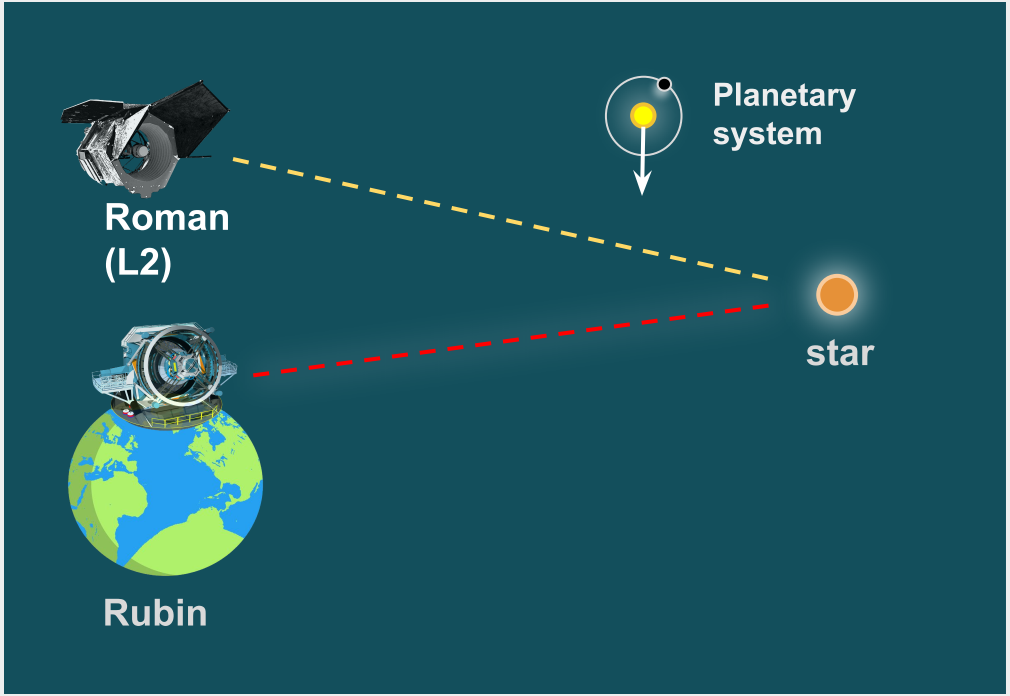
A microlensing event occurs when two unrelated objects as two stars line up along the observer line of sight

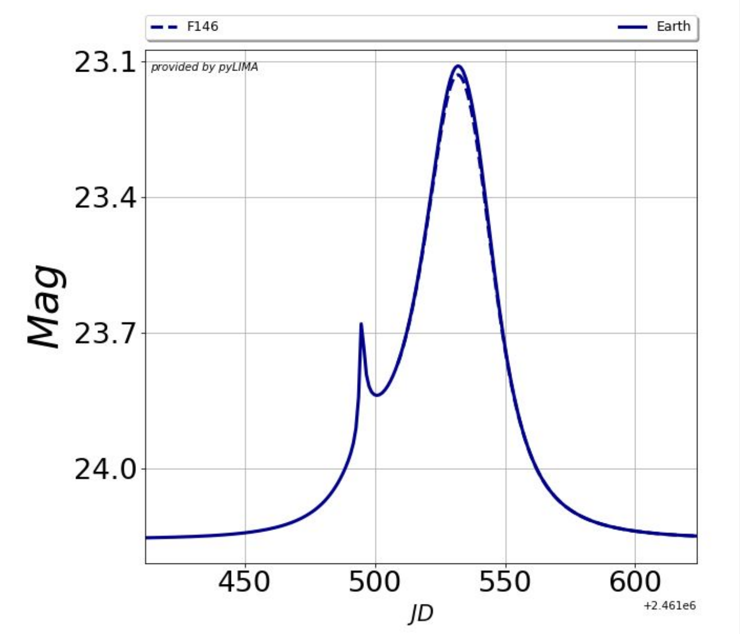
We study events with binary lens. This model depends on 8 parameters:

- the impact parameter u_0
- the time of maximum magnification t_0
- the time scale t_E
- the mass ratio q of the lenses and their separation s
- the angle α and the parallax vector whose components are π_{EN} π_{EE}



Satellite parallax with binary lens





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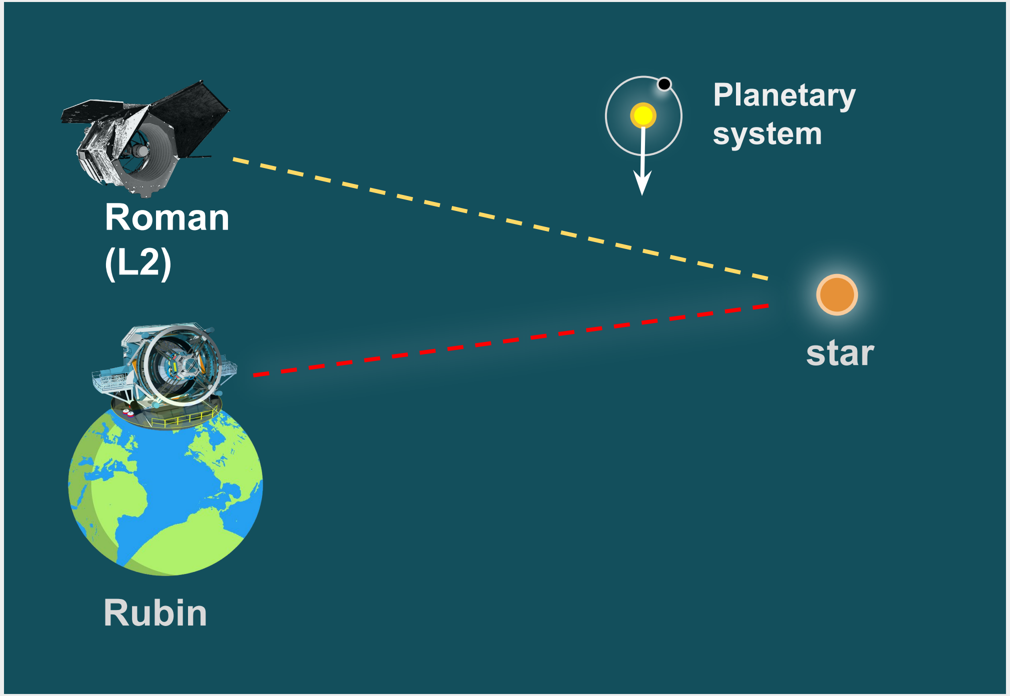
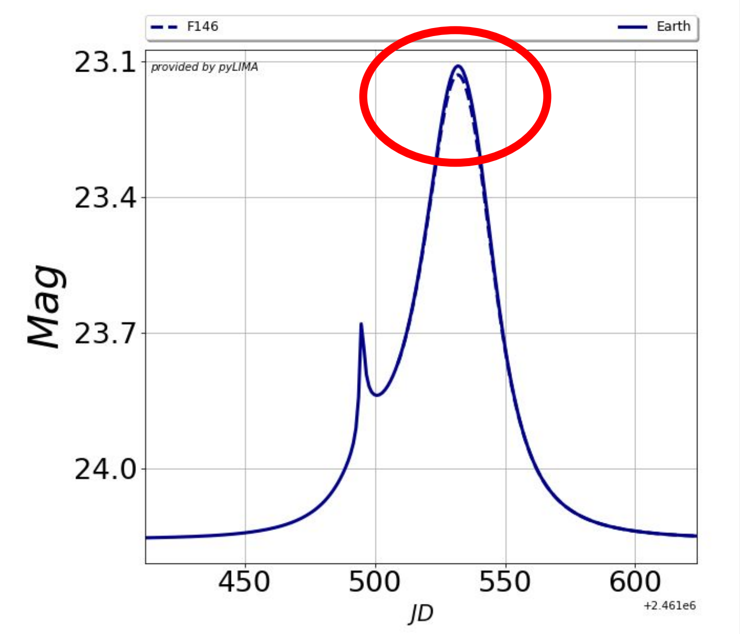
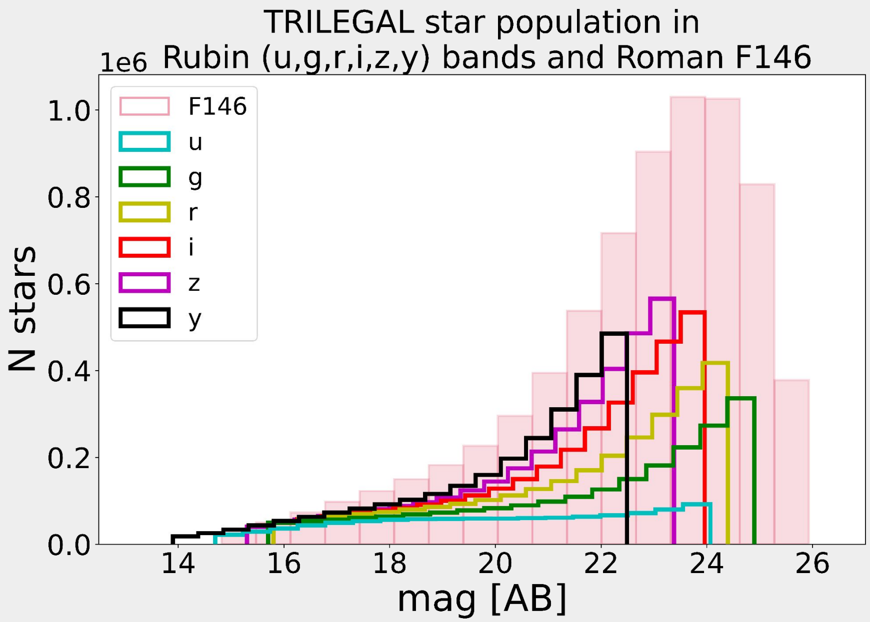




Simulation of microlensing light curves

Source properties simulated from TRILEGAL (Leo Girardi et. al)



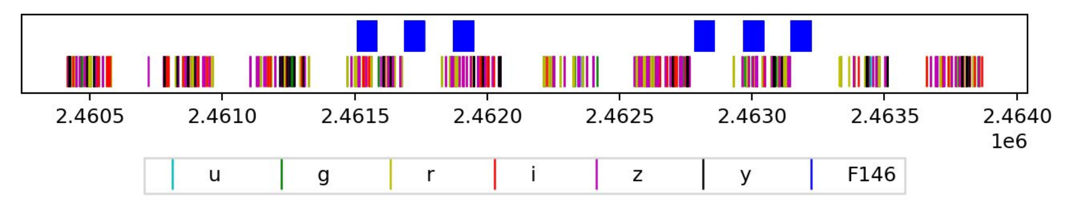
The simulation is made in one point of Rubin observatory that includes the Roman fields.

This provides the properties of the star and the magnitude in the Roman and Rubin bands.

We take into account the limiting magnitudes and saturation magnitudes in each passband for both telescopes.

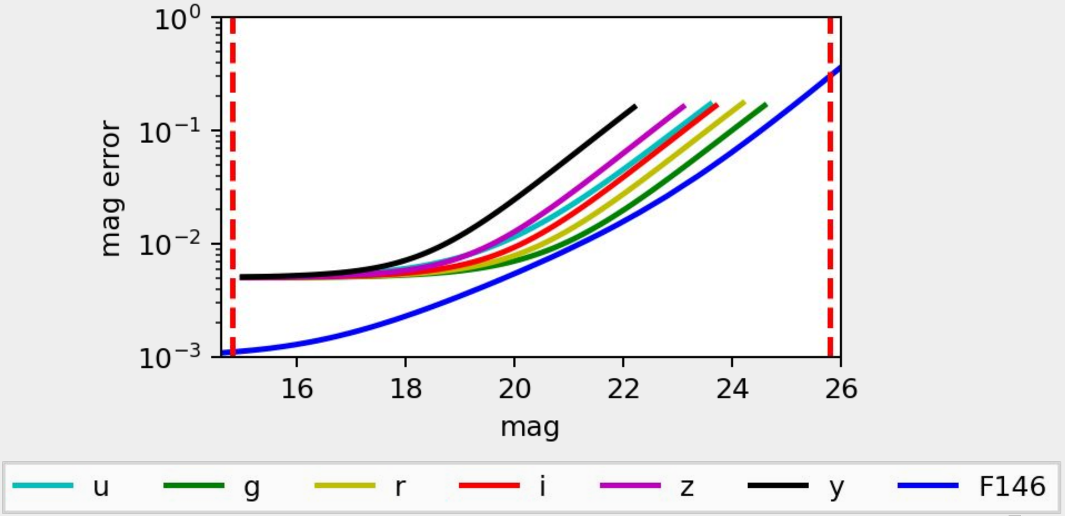
Simulation of microlensing light curves

Cadence and noise models



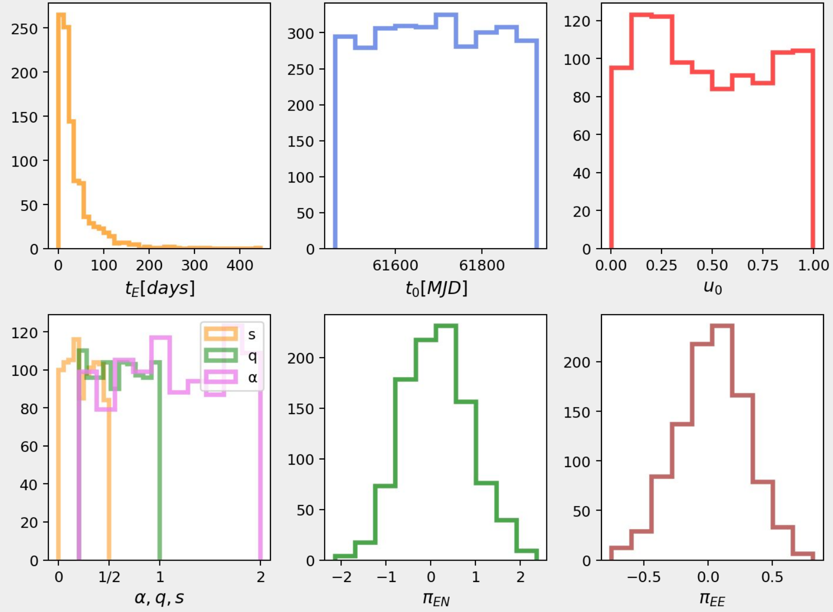
Rubin: obtained from simulation OpSim *baselinev2.0* with the models for magnitude errors.

Roman: Cadence and noise model obtained from Peny et al (2015) using pyLIMA software (Bachelet et al 2017).

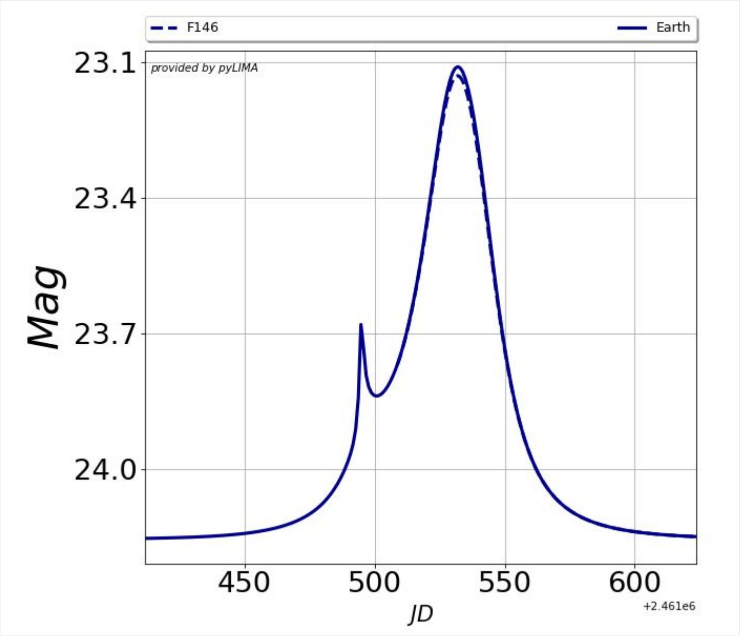


Binary lens event parameters

Parameter distributions

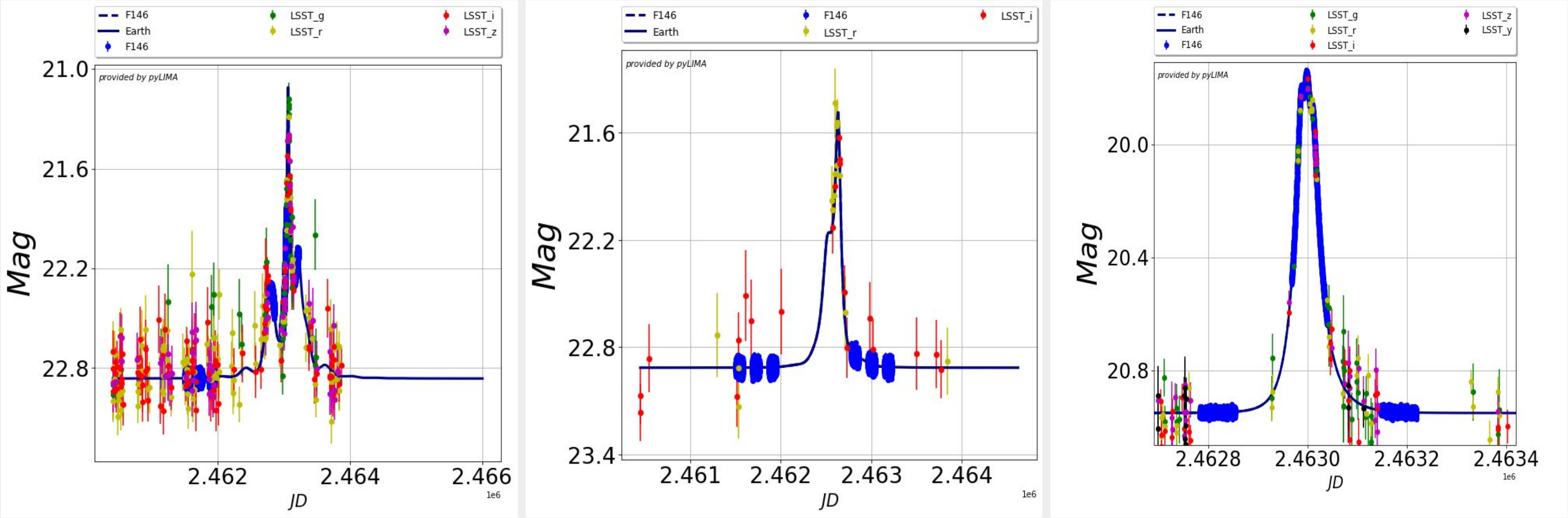


t_0	u_0	t_E	s	q	α	π_{EE}	π_{EN}
2461526.24	0.42	23.22	0.11	0.71	0.31	0.23	0.80



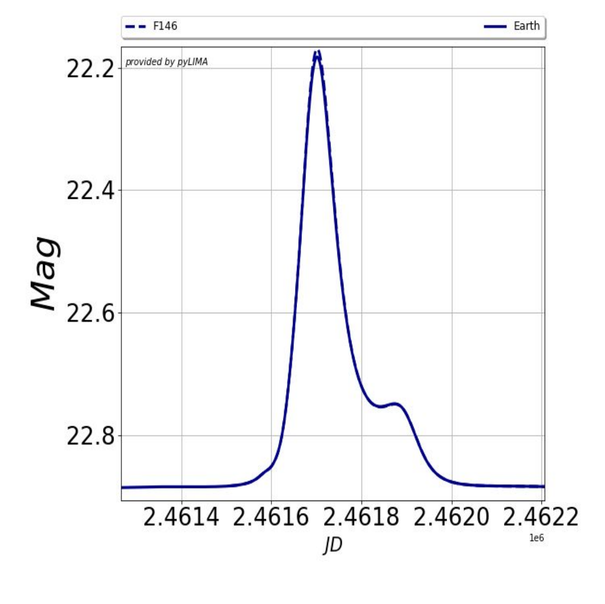
Event selection

Selected events

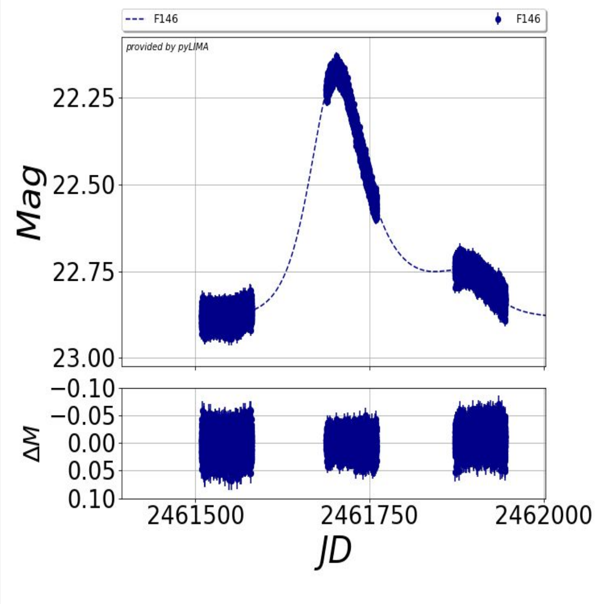


Some examples of fitting using TRF algorithm with PyLIMA

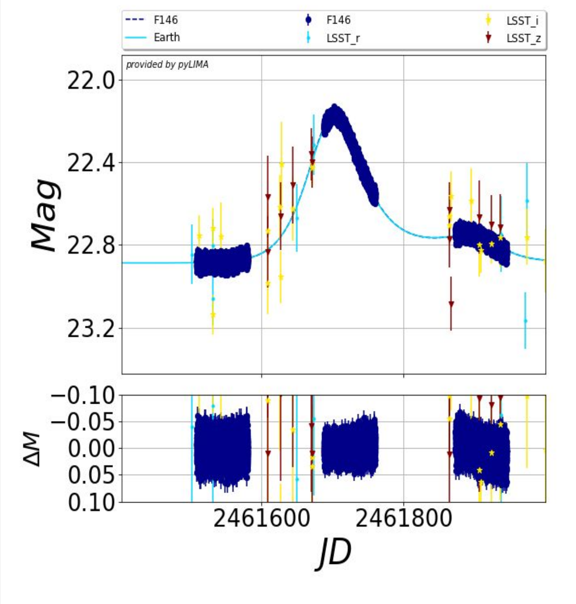
True model



Fit with only Roman data



fit with Roman + Rubin



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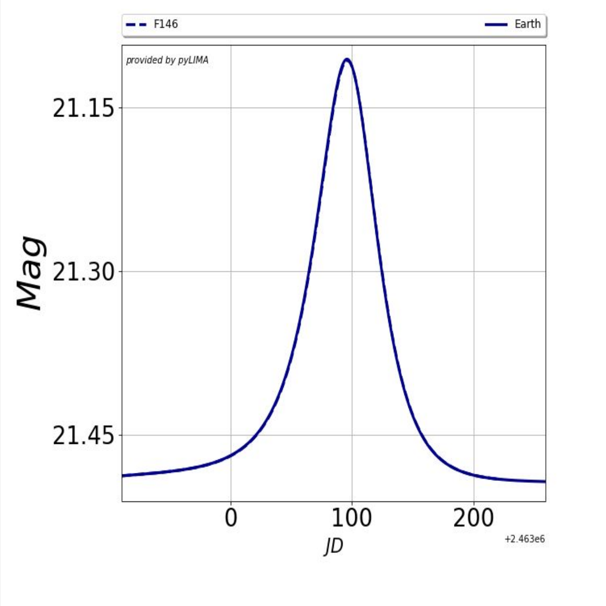
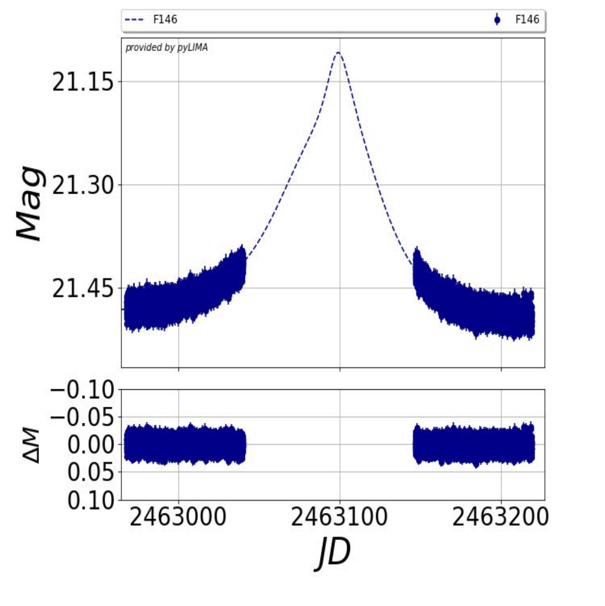
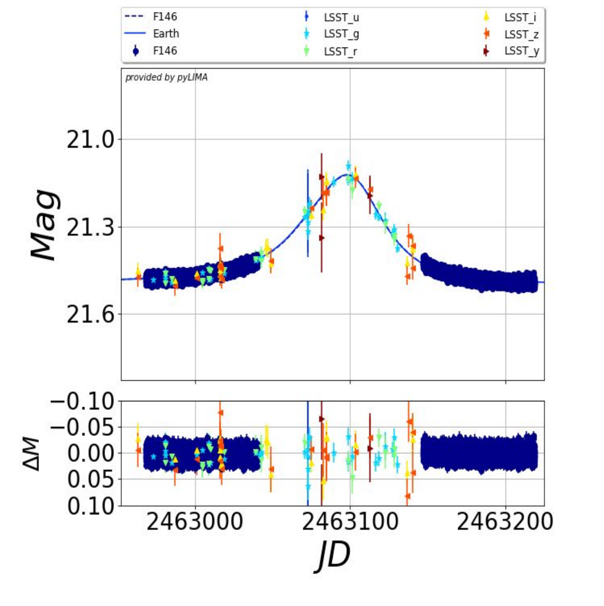


Fit with only Roman data



fit with Roman + Rubin



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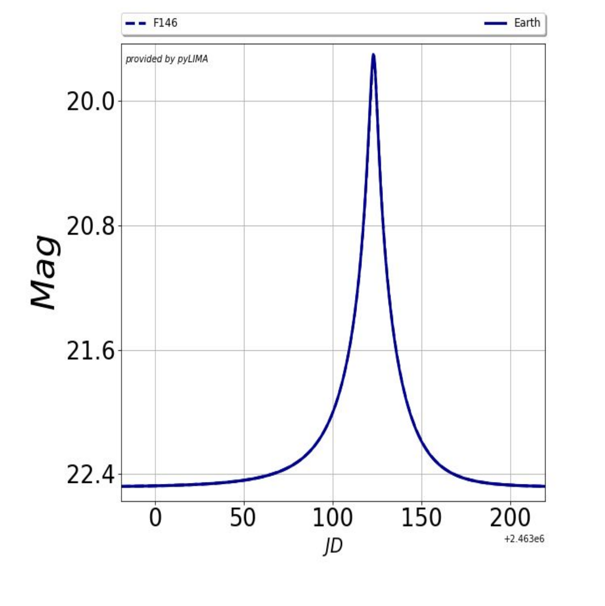
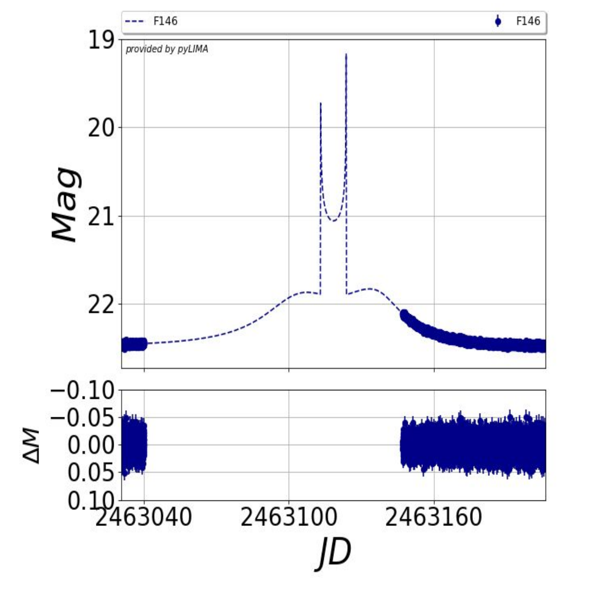
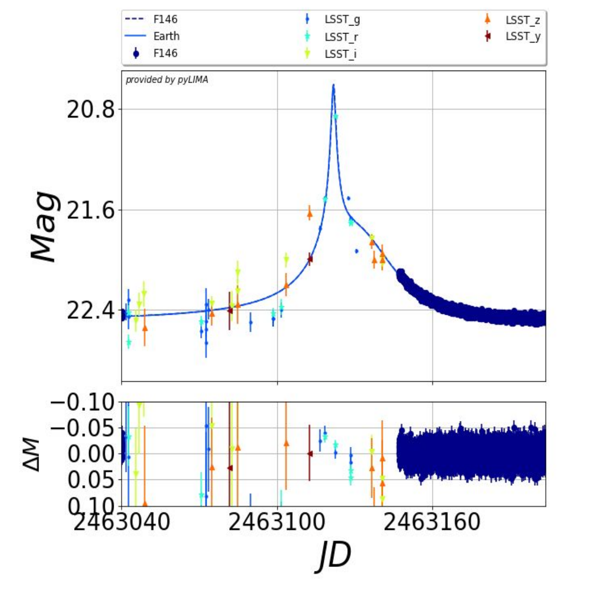


Fit with only Roman data



fit with Roman + Rubin



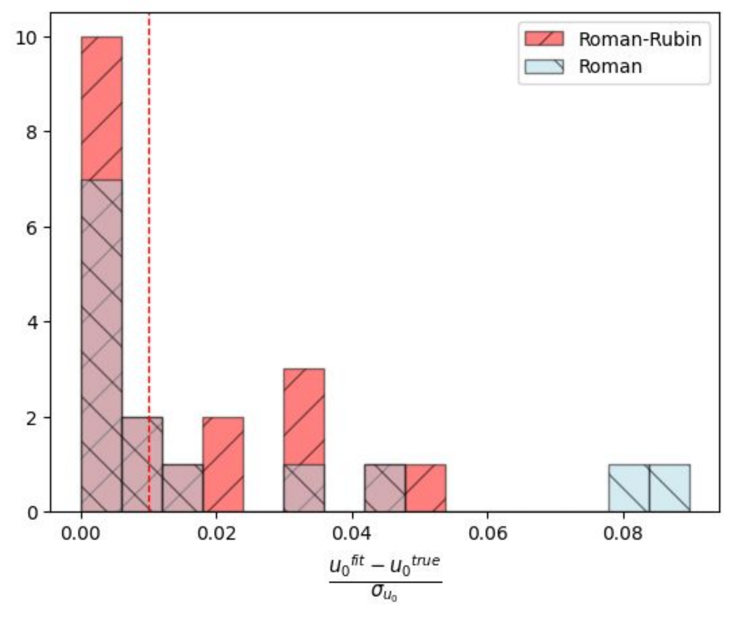
Evaluating metrics to assess the impact of Rubin data

- Goodness of the microlensing LC fit
- Fractional error of recovered values x input values
- Fraction of events well fitted (or with well recovered parameters)
- Accuracy: Bias with respect to inputs and with uncertainties
- Precision: Relative value of recovered uncertainties
- Fraction of events with uncertainties or bias below a given threshold

Comparing values for all the 8 LC parameters.

Next:

- Understand/fix cases where pyLIMA seems to fail
- Nail down classes of events where Rubin has a larger impact
- Focus on interesting parameters (e.g. parallax)



Histogram of bias relative to the estimated uncertainty for the impact parameter from the pyLIMA fits.

Final remarks

- This work is in progress.
- Simulation pipeline is ready (and can be applied to any OpSim).
- Exploring metrics to estimate the improvements of the combination of Rubin + Roman data.
- Will focus on specific subsets of events.
- The fitter algorithms are a relevant issue, there are unexpected behaviors for a fraction of the events that need to be further explored.
- When this part it’s ready we can study how the different strategies of observation of Rubin (and Roman) can impact the characterization of the microlensing events.

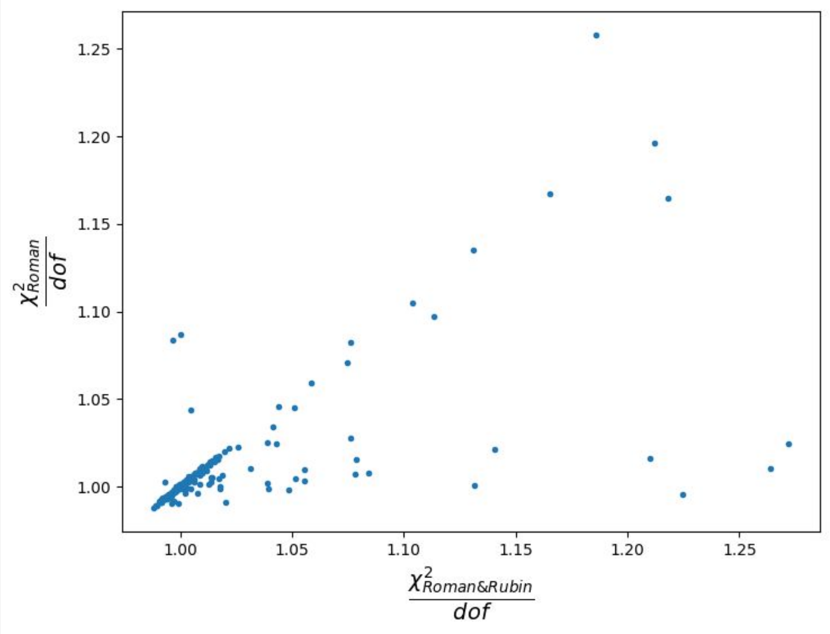
Thank you!

Strategies to evaluate the results

We use several metrics to evaluate the enhancement of this characterization in the set of events, some of them are

$$\chi^2 = \sum_i^N \left(\frac{y_i - f_i}{\sigma_i}\right)^2$$

This estimator is useful to know if the data is compatible with the model fitted but give no information about how the parameters found far from the true model.



Event selection

- Consider only the points that are within 1 sigma distance from the limiting magnitude. And at least 1 at 5 sigma.
- Consider only the events that have Roman and Rubin bands.
- There are at least 10 points in any filter.
- The brightest point corresponds to 1.34 magnification.
- Consider the points that fall within the time range of t0 ± 5tE and compute their mean value; this will serve as the magnitude baseline.
- Compute the chi-squared value for the entire light curve, assuming a constant baseline magnitude model as previously computed.

$$\chi^2 = \sum_i^n \left(\frac{y_i - m}{\sigma_i} \right)^2$$

- If the chi-squared value is > 2 in any filter, consider it as an event.

Event selection

Events not selected