Microlensing towards the Magellanic Clouds: searching for long events

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1 Introduction

Microlensing occurs when a massive compact object transits on the line of sight of a background source, temporarily magnifying its light. The search for microlensing toward the Magellanic Clouds is specific because it probes mainly the Galactic dark matter halo component made of compact objects. Low signal rate is therefore expected, and since the past surveys have established stringent constraints on stellar and sub-stellar mass objects [Moniez 2010, Wyrzykowski et al. 2011], the search for intermediate and high mass black holes is the most promising toward LMC/SMC [Blaineau 2021]. This search concerns very long time-scale events (up to several years) and will need to sample LMC/SMC fields along the 10 years of the survey [Mirhosseini & Moniez 2018].

In order to be able to compare different cadencing simulations, we define a simplified estimate of the detection rate of microlensing events. It is based on the simulation of microlensing light curves for a star of magnitude 20 in every filter, at the center of the LMC. Each point-source point-lens rectilinear microlensing event is characterized by only three parameters, and we generate uniformly these parameters in the following ranges : impact parameter $u_0 \in [0;3]$, Einstein duration $\log_{10}(t_E) \in [0;3]$ and time of maximum magnification t_0 between the first and last measurements taken toward the LMC. We estimate the photometric uncertainties along the simulated light curves using the expressions given in the LSST science book [LSST sciencebook 2009]. We then compare the χ^2_{ml} of a simulated light-curve relative to the theoretical microlensing curve and the χ^2_{flat} relative to a stable (constant) light curve. A microlensing event is considered as detected as soon as the difference $\Delta\chi^2 = \frac{\chi^2_{flat} - \chi^2_{ml}}{\sqrt{2N_{dof}}} > 80$. We also require to have 5 flux measurements more than 3 sigmas above the baseline to eliminate light curves with too few meaningful measurements. Obviously, as mentioned before, this is only a tool to compare different OpSims and it not sufficient to compute a true detection efficiency, since a real analysis needs criteria to reject many types of periodic or non-periodic variable objects. As far as long time scale events are concerned (several years), it has been shown in [Blaineau & Moniez 2020] that the parallax has a negligible impact on the efficiency detection and there is no need for a more complex simulation tool.

2 Survey Footprint

Q1: Are there any science drivers that would strongly argue for, or against, increasing the WFD footprint from 18,000 sq. deg. to 20,000 sq.deg.? Note that the resulting number of visits per pointing would drop by about 10%. If available, please mention specific simulated cadences, and specific metrics, that support your answer.

The footprint should include LMC or/and SMC (ideally, 4 pointings toward the LMC inner regions centered on (l=280.5,b=-32.9), and/or one pointing toward the SMC centered on (l=302.8,b=-44.3)). The detection rate is significantly better if the LMC is included in the WFD, as shown in figure 1, since the number of measurements toward LMC is three times larger.

Q2: Assuming that current system performance estimates will hold up, we plan to utilize the additional observing time (which may be as much as 10% of the survey observing time) for visits for the mini-surveys and the DDFs (with an implicit assumption that the main WFD survey meeting SRD requirements will always be the first priority). What is the best scientific use of this time? If available, please mention specific simulated cadences, and specific metrics, that support your answer.

The best use of this time for the science case discussed here would be to take a few hundred of images towards 4 LMC fields over the 10 years of the survey, which represents a total cost of observations of less than 40 hours, assuming a total of 4×1000 images (all filters included).

3 Exposure time per visit

Q3: Are there any science drivers that would strongly argue for, or against, the proposal to change the u band exposure from 2x15 sec to 1x50 sec? If available, please mention specific simulated cadences, and specific metrics, that support your answer.

No special constraint.

4 Allocation of observing time per band

Q4: Are there any science drivers that would strongly argue for, or against, further changes in observing time allocation per band (e.g., skewed much more towards the blue or the red side of the spectrum)? If available, please mention specific simulated cadences, and specific metrics, that support your answer.

Microlensing is (if one neglects the blending) an achromatic process, that can be searched for within multi-band light-curves. Nevertheless, as far as photometric accuracy is concerned, the bands that maximize the light (griz) are always preferable.

5 Time sampling and revisit offsets

Q5: Are there any science drivers that would strongly argue for, or against, obtained two visits in a pair in the same (or different) filter? Or the benefits or drawbacks of dedicating a portion of each night to obtaining a third (triplet) visit? If available, please mention specific simulated cadences, and specific metrics, that support your answer.

Since we are searching for years long microlensing events, the variation within the same night is negligible, and several measurements can only be useful to reject possible artifacts.

Q6: Are there any science drivers that would strongly argue for, or against, the rolling cadence scenario? Or for or against varying the season length? Or for or against the AltSched N/S nightly pattern of visits? If available, please mention specific simulated cadences, and specific metrics, that support your answer.

The expected number of detected long timescale microlensing is almost insensitive to the details of the cadencing, as long as the observations are spread reasonably uniformly over the 10 years of the survey, as it can be seen on figure 1. Although the rolling cadence strongly improves the efficiency of detection of short events (rare in LMC/SMC) during the 2 or 3 years when it is effective, its impact averaged over the 10 years is globally a loss of efficiency. Nevertheless, the detection of long duration events remains unchanged.

It is also worth noting that considering longer observing seasons (with a constant number of measurements) in *baseline_nexp2_v1.7.1* would greatly increase the detection rate for shorter microlensing events without decreasing efficiency for longer events.

We conclude that the search for long time-scale events is not sensitive to the details of the cadencing, as long as a few hundred measurements are spread over the 10 years of the survey. In the worst case scenario, if we were to miss one or several years of observations, we show in figure 2 what the impact would be on detection rate. Missing more than one year of observation would start to really hurt the detection rate, even for long time scale events. These curves are also optimistic since we know by experience that the risk of selecting rare types of variable stars in a real microlensing search analysis increases with the incompleteness of the sampling.

It is essential for long timescale events to have observations toward the LMC as early and as late as possible over the duration of LSST to be sensitive even to the longest microlensing events.

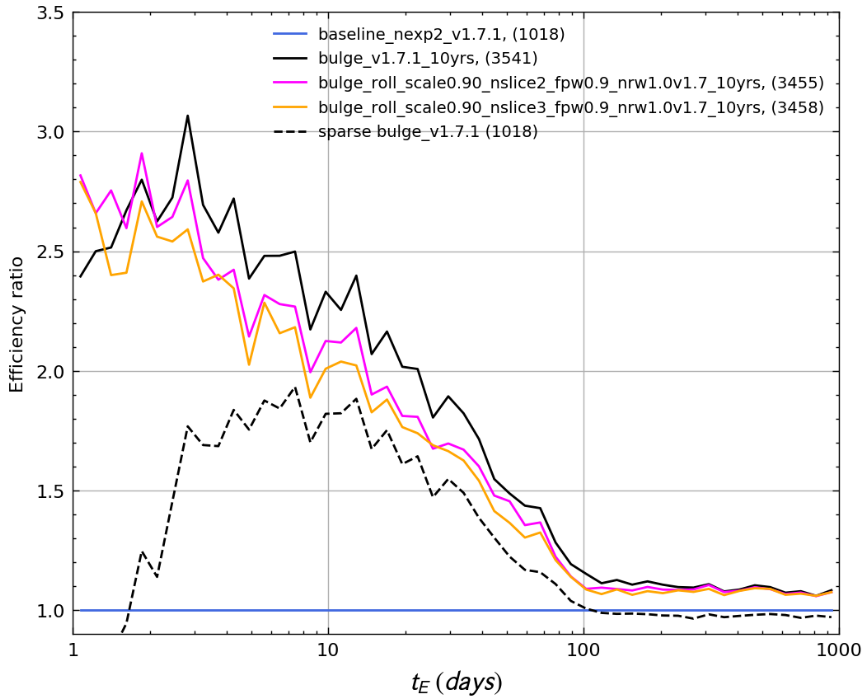

Figure 1: Efficiency ratios relative to the baseline as a function of the microlensing event Einstein times for different OpSims. The numbers in parentheses are the total numbers of measurements for each OpSims. The *sparse bulge_v1.7.1* (black dotted line) is the *bulge_v1.7.1_10yrs* OpSim for which we randomly eliminated 2523 points to have the same number of measures as in the *baseline_nexp2_v1.7.1*. This strategy is especially more efficient than the *baseline_nexp2_v1.7.1* for events between 1 and 100 days. This is due to the spread of observations in longer observing seasons than for *baseline_nexp2_v1.7.1*.

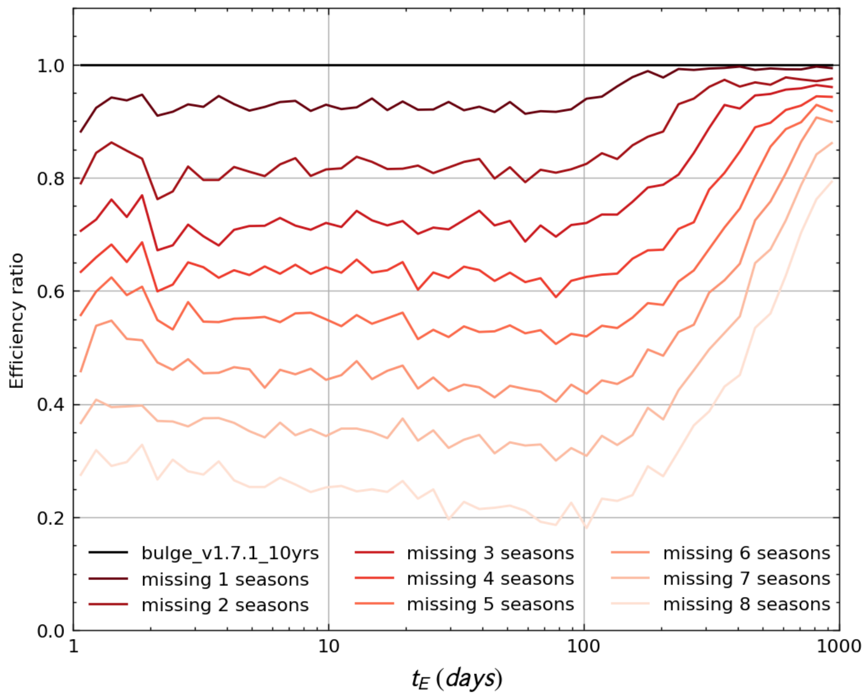

Figure 2: Efficiency ratio as a function of the microlensing event Einstein time when removing 1 or more years of observation from the *bulge_v1.7.1* OpSim. We remove one or more consecutive years of observations starting from the second, always keeping the first and last year of observations.

Q7: Are there any science drivers pushing for or against particular dithering patterns (either rotational dithers or translational dithers?) If available, please mention specific simulated cadences, and specific metrics, that support your answer.

Not applicable.

6

References

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