Gravitational Microlensing seen by Gaia Space Satellite

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Up to this day Gaia has detected around 3000 transients through its alerting system called *AlertPipe*. More than twenty events found this way are gravitational microlensing event candidates. However, at least one event found by other surveys was omitted by *AlertPipe*. The main goal of this research was to create a new alerting method for Gaia tailored specifically to detect new microlensing events, that would aid an already existing pipeline. An additional goal was to check if any other candidates have been overlooked.

1 Introduction

On 19th Dec. 2013 Gaia Space Satellite was launched by European Space Agency (ESA). Its main goal is to measure parallaxes of over 1 billion stars in Milky Way (European Space Agency, 2016a). However, ever since first data has been acquired in 2014, Gaia has observed much more than that. Up to this day, its alerting system of sudden change in brightness of observed sources (*AlertPipe*) has detected around 3000 transients. Up to Dec. 2017, more than twenty of them were classified as microlensing candidates with spectacular Gaia16aye (European Space Agency, 2016b) event among them. Unfortunately, at least one event – ASASSN-16oe (Strader et al., 2016) detected by All Sky Automated Survey for SuperNovae was not found by the Gaia alerting system.

2 Method

AlertPipe data from Gaia has been investigated for around 1.5 million sources. One million microlensing lightcurves have been simulated with photometric error and time of observations similar to data found in Gaia. Their Einstein time t_{E} has been randomly chosen from the range between 20 and 200 d, brightness in base line m_0 from the range between 14.5 and 19.5 mag and impact parameter u_0 from 0 to 1. For all lightcurves, six statistical parameters have been calculated: mean, median, standard deviation, amplitude of brightness, skewness of the brightness histogram γ_1 and von Neumann parameter η for lightcurves.

3 Results

Simulations show that microlensing events tend to occupy a specific area on the $\gamma_1 - \eta$ parameter space. In the Gaia *AlertPipe* database of the regions containing Gaia16aye and ASASSN-16oe, around 43% of the sources have median of brightness smaller than 19.0 mag. Around 7% of them have amplitude greater than 1.0 mag. Out of these, no new microlensing candidates have been found. Around 200 sources

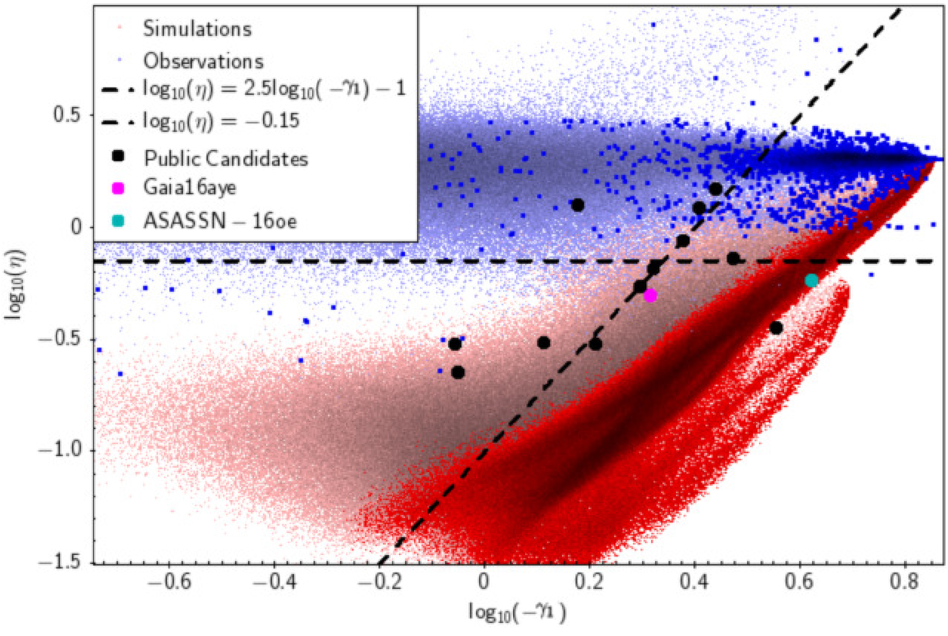

Fig. 1: Plot of the $\log_{10}(\gamma_1)$ – $\log_{10}(\eta)$ parameter space for synthetic microlensing lightcurves (red dots) and *AlertPipe* data from Gaia (blue dots). Large red and large blue dots denote sources with median of brightness smaller than 19 mag and amplitude larger than 1 mag. Big, black dots mark public Gaia microlensing candidates, Gaia16aye and ASASSN-16oe are highlighted in pink and teal color respectively.

mimicked microlensing events due to instrumental effects. The positions of light curves on $\gamma - \eta$ plot for simulated events, together with public Gaia microlensing candidates and other sources found in *AlertPipe* database, are presented in Fig. 1.

The position on the $\gamma_1 - \eta$ plot depends on the timescale of the event t_E, impact parameter u_0, completeness of the lightcurve and how often the source was observed. While an event occurs, it moves in a distinctive way on $\gamma_1 - \eta$ plot. This provides a hint, on how to distinguish microlensing candidates and how to choose a range of parameters where new alerting tool should operate. Area with the least contamination from false positive microlensing candidates and least amount of false negatives has been marked in Fig. 1. Fig. 2 shows how an event is moving in $\gamma_1 - \eta$ parameter space.

4 Future work

The research shown here presents a foundation on which a new alerting tool will be build and implemented into an already existing pipeline for Gaia transients. However, one can observe that Gaia satellite does not provide sufficient data for proper modelling of microlensing event. In order to improve lightcurves of future microlensing candidates, ground observations of all Gaia events will be conducted. Additionally, in order to confirm the nature of a microlensing candidate, spectra near peak brightness and after the event will be provided by ESO/X-SHOOTER

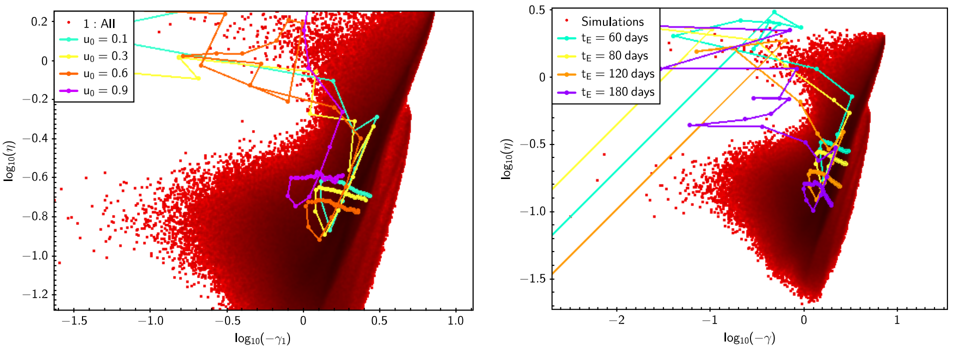

Fig. 2: Plots of $\log_{10}(\gamma_1)$ – $\log_{10}(\eta)$ parameter space for synthetic microlensing lightcurves (red dots) and trajectories of synthetic lightcurves for microlensing event. Left panel shows the case where impact parameter u_0 has fixed value of 0.1 and time of the peak of brightness $t_0$was occurring in the middle of observations. Right panel shows the case where timescale parameter (Einstein time) t_{E} has fixed value of 80 d and time of the peak of brightness t_0 was occurring in the middle of observations.

and SALT/RSS telescopes.

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