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Optical transients, detected by MASTER Global Robotic Net in LIGO/Virgo G297595 error-box

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Abstract. We present MASTER observations from inspecting the large error-box associated with LIGO/Virgo G297595 as the result of our observational strategy to inspect large error-fields with maximum efficiency. MASTER observed 642 square degrees inside the 3σ error box. We present optical sources detected during this inspection.

Introduction

The discovery of gravitational waves by aLIGO experiment offers a prospect of exploring the Universe in a fundamentally new range (Abbott et al. 2016abc). The experience of optical support for the first observations shows that optical localization of GW events is an extremely difficult task for two reasons. First, most of the detected events were associated with black-hole mergers (in full agreement with prediction, calculated at Scenario Machine by Lipunov et al. 1997abc). The second is the short time that such extreme object can be available for observers in any electromagnetic range. The third is large error-boxes of all GW events, that should be inspected in short time to discover such short live objects in electromagnetic range and to get its energy distribution to understand its nature.

MASTER Global Robotic-telescope network (Lipunov et al. 2010) worked equally intensively for all GW events, regardless of their nature. As a result, the MASTER network made crucial contribution to the optical inspection of the first-ever GW event in history, which occurred on September 14, 2015, by observing 90% of the final error box of GW 150914 (Abbott et al. 2016d) down to a deep limiting magnitude ($\sim 19-20^m$). In 2017 (O2), MASTER independently discovered the Kilonova in the NGC4993 galaxy before the publication by the observers at the Swope telescope (Abbott et al. 2017; Lipunov et al. 2017) and participated in the inspection of 20 GW gravitational-wave alerts during two sets of 2015 (O1) and 2017 (O2).

Here we present short results of LIGO/Virgo G297595 error-box optical observations by MASTER.

MASTER observations strategy

During the first set of observations, gravitational-wave bursts detected by aLIGO LIGO/ Virgo in O1, O2, O3 sets of work were distributed by GCN alert system (Barthelmy et al. 1998). MASTER network, designed to discover and investigate high energy astrophysics sources like gamma-ray bursts events, gravitational wave events, high energy neutrino events and other, connected to GCN services directly from each observatories (MASTER-Amur, -Tunka, -Kislovodsk, -Tavrida, -SAAO, -IAC, -OAFA, OAGH) and from the center (Moscow MASTER database). Our key factors are distribution around the Earth, fast pointing, identical photometric system at every node, and real-time reduction with new OT detection.

MASTER works in several modes: alert, inspection and own survey. The main criteria for any sky survey are its completeness (coverage) and rate. Because of this, telescopes must be able to cover the sky with as close survey sites as possible. Therefore, it is necessary to divide the sky into fields of a given size, slightly smaller than the telescope's field of view, in order to have overlaps. In the case of the MASTER network, the sky is subdivided into $\sim$ 10000 fields and tried to observe large error-fields by these squares for making the difference between current and archive images for the better extraction of faint new objects or the objects at the galaxy discs (SNe). Our Central Scheduler ensures that the image from the alert location has been captured by at least one telescope in the network, then controlled limit magnitudes of it and can distributed squares between other MASTER telescopes.

The main unique feature of the MASTER is own software, which has been developed for more than 20 years, and which made it possible to detect new optical transients (OT) in MASTER wide-field images in 1–2 min after reading from the CCD. This information includes full classification of all sources in the image, data from previously archived MASTER images for each source, complete information from the VIZIER database and from all open data sources (for example, the Minor Planet Center), derivation of orbital elements for moving objects, etc. In search-type problems, images of real astrophysical sources are unlikely to consist of only one, two, or four pixels—such sources are most likely artificial and are eliminated by the search program. Real transient images should cover several pixels distributed according to a certain profile.

The MASTER network software detects OT not by the difference between previous and current images, but by the complete identification of each source in each image. If there is a galaxy nearby, the software automatically classifies the OT as a PSN, after it we manually check its position to detect any faint Milky Way object (fainter than the optical limit) along the line of sight found in the archived MASTER or POSS/SDSS/PanSTARRS images. M31 image analysis with MASTER should consider the detection of a possible nova in M31. If VIZIER sources are not found within $5''$ of the assumed coordinates, and the light curve (LC) is presented for at least one or two nights, this may be a cataclysmic variable (in most cases, U Geminorum). If there is a rise in the LC, and then the source disappears again within a few tens of minutes, and a red or infrared object is detected in the VIZIER, we can talk about a UV Ceti star flare. All OTs were checked in MPC to exclude moving objects.

GW170814/G297595 error-fields observations

The gravitational wave event GW170814/G297595 is connected with binary black hole merging, that was registered by LIGO/Virgo detectors on 2017-08-14 10:30:43UT. The

distance to event was calculated by LIGO/Virgo collaboration as 534.286 ± 131.305 Mpc.

MASTER telescopes automatically received GCN alert on 2017-08-16 13:55:32UT and started error-field observations on 2017-08-14 22:10:06UT at MASTER-Kislovodsk, -Tunka, -Amur, -Tavrida, -SAAO, -IAC, -OAFA, covered 642 square degrees inside 3σ error area (77.5% of full probability LIGO/Virgo map).

During inspection we found the following optical transients, not related with BBH merging, but they are an indicator of our strategy methods and observations effectiveness.

MASTER OT J025621.23-410127.9 — CV outburst, found by MASTER auto-detection system at (RA, Dec) = $02^h56^m21.23^s$, $-41°01'27.9''$ on 2017-08-14.97697 UT with unfiltered magnitude 19.5^m ($m_{lim} = 20.4^m$). The OT was seen in 3 images. We have referent images without OT on 2015-02-09.83389 UT with unfiltered $m_{lim} = 20.8^m$, on 2017-08-15 05:22:25 with $m_{lim} = 20.0^m$ (too fast decay for red star), on 2020-11-20 ($m_{lim} = 20.80^m$), 2017-10-11 23:21:54UT ($m_{lim} = 20.4^m$), 2017-06-06 10:16:09UT ($m_{lim} = 20.6^m$), 2016-12-24 03:49:22UT ($m_{lim} = 20.90^m$). There is variable source in VIZIER database (USNO-B1 R1=20.86^m, B2=21.18^m, The Dark energy survey $r_{mag} = 10.14^m$, $i_{mag} = 19.8^m$).

MASTER OT J020509.33-334858.7 CV outburst, found by MASTER auto-detection system at (RA, Dec) = $02^h05^m09.33^s$ $-33°48'58.7''$ with unfiltered $m_{OT} = 18.71^m$, and nearest non-detection on 2017-08-16 05:53:28.51UT with $m_{lim} = 20.5^m$. Reference images in history are on 2018-08-10 09:04:42 with $m_{lim} = 19.8^m$, 2018-08-13 01:19:52 $m_{lim} = 20.5^m$.

MASTER OT J030141.96-230037.8 — short OT, found by MASTER auto-detection system near PGC 806045 at (RA, Dec)=$03h01m41.96s$, $-23°00'37.8''$ on 2017-08-16 07:17:07 UT with unfiltered magnitude 17.5^m ($m_{lim} = 19.7^m$). The OT was visible in two images. We have reference image without the OT at 2017-03-10. 01 UT, with a unfiltered limiting magnitude 18.6^m.

Conclusions

We presented several optical transients, detected by MASTER auto-detection system in 2018 during LVC optical support. They demonstrates efficiency of inspect survey, but not connected with BBH event.

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Оптические транзиенты, обнаруженные роботизированной сетью MASTER Global в окне ошибок LIGO/Virgo G297595

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Резюме.Представлены наблюдения сети MACTEP при проверке поля ошибок, связанного с событием LIGO/Virgo G297595. Всего MACTEP наблюдал 642 квадратных градуса, соответствующих полю ошибки 3σ. Перечислены оптические источники, обнаруженные в ходе этой проверки.