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Research Article

Master Robotic Net

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The main goal of the MASTER-Net project is to produce a unique fast sky survey with all sky observed over a single night down to a limiting magnitude of 19-20. Such a survey will make it possible to address a number of fundamental problems: search for dark energy via the discovery and photometry of supernovae (including SNIa), search for exoplanets, microlensing effects, discovery of minor bodies in the Solar System, and space-junk monitoring. All MASTER telescopes can be guided by alerts, and we plan to observe prompt optical emission from gamma-ray bursts synchronously in several filters and in several polarization planes.

1. Introduction

The MASTER project (Mobile Astronomical System of TElescope Robots) was launched in 2002, when the first Russian robotic telescope was installed near Moscow on an automated mounting with automatic roof, weather station, and alert system (Lipunov et al. [1–3]). By early 2008 we posted about 100 GCN circulars, recorded optical emission from three gamma-ray bursts, and discovered four supernovae (Lipunov et al. [4], Tyurina et al. [5]). Unfortunately, very poor astroclimatic conditions near Moscow made it impossible to demonstrate the potential of our telescope to its full extent. However, we obtained about 80 000 images, each with a size of six square degrees, and used them to successfully develop a software pipeline, which allows us not only to perform in real time the extraction of images and their astrometric and photometric reduction, but also to automatically classify the sources identified; that is, determine which type of astronomical objects (supernovae, minor planets, comets, man-made satellites, meteors, or optical transients) they belong to (Figures 1 and 2). Moreover, our facility can also be used for alert observations of optical emission of gamma-ray bursts (Tyurina et al. [5]).

Our experience with the operation of robotic telescopes allowed us to develop the wide-field MASTER optical facility with optimum parameters, which can be used to address a wide range of astrophysical tasks. We actually developed a multipurpose optical facility, which is similar in composition to the one independently proposed by Bogdan Paczynski (Paczynski [6]). The first MASTER telescopes and their individual components are already installed at three sites in Russia—near Kislovodsk (Caucasian Mountain Observatory of the Sternberg Astronomical Institute of the Moscow State University), in Urals (Kourovka Observatory of Ural State University), and near Irkutsk (Irkutsk State University Observatory). In summer 2009 we also plan to deploy similar facilities near Irkutsk and Blagoveshchensk.

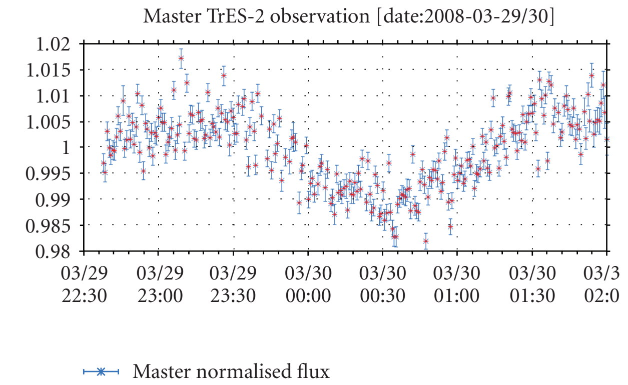

Figure 1: Folow-up exoplanet transit observations by MASTER (Moscow).

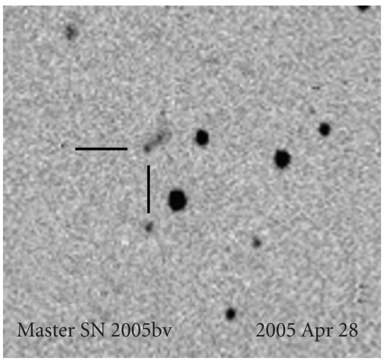

Figure 2: The first supernova discovered in Russia (SN2005bv).

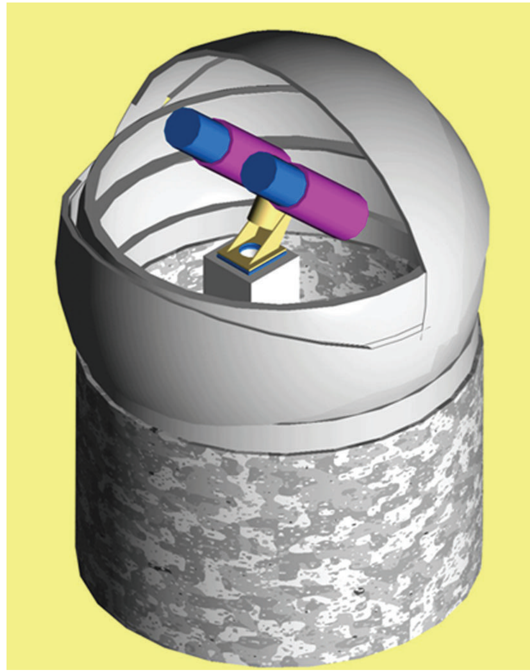

Figure 3: MASTER II wide-field robotic telescope (manufactured by OAO Optika Moscow Association). Each tube is equipped with a photometer with a set of B, V, R, I filters and polarizers.

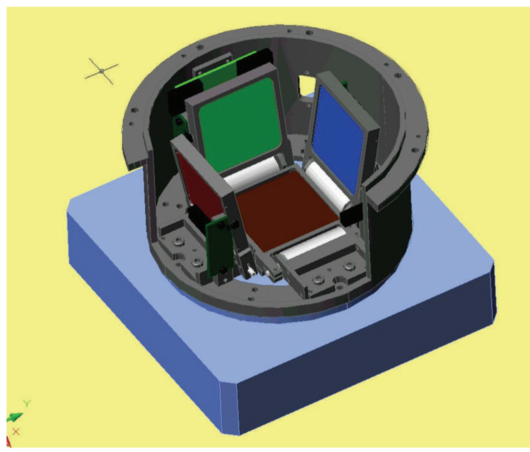

Figure 4: Photometer with 3 filters and 1 polarimeter based on an Apogee AltaU16M CCD camera.

2. MASTER Wide-Field Robotic Facility

The MASTER wide-field robotic telescope that we developed is manufactured by OAO Optika Moscow Association. The facility consists of two instruments: MASTER II wide-field optical telescope "Santel 400" and MASTER very wide-field (VWF) cameras.

2.1. MASTER II Wide-Field Robotic Telescope. A single fast German equatorial mounting carries two 1 : 2.5 focal-ratio symmetrical high-aperture 400-mm catadioptric telescopes (Figure 3). The telescope has an extra degree of freedom, which allows their tubes to be aligned or misaligned, making it possible to double the size of the field of view and, when operating in the alert mode (with collinear tubes), to perform synchronous photometry of rapidly varying objects in standard broad-band filters (B,V,R,I) and their polarimetry at different polarizations (Figure 4).

Table 1 lists the technical parameters of MASTER II telescope. The telescope is equipped with a shell-type automatic shelter, which, when open, allows the entire sky to be observed. This facility is also equipped with a time synchronization system, a weather station, and a cloud cover sensor.

2.2. MASTER VWF Very Wide-Field Camera. V. G. Kornilov developed a robotic very wide-field MASTER VWF camera with a maximum field of view of 1000 square degrees (Figure 5) for synchronous observations of optical emission from gamma-ray bursts. The facility uses a parallactic fork capable of carrying 2 CCD cameras with up to 10-cm aperture lenses. The facility has an autonomous high-quality roof designed by N. I. Shatskii. Our experience of its operation under extreme conditions of Russian winter (with temperatures as low as −40 degree Celsius) demonstrates good survival potential of all systems. Table 2 lists the specifications of the very wide-field camera. The cameras are adapted to all large-aperture Nikor and Nikor-Ziess lenses.

Table 1: Composition and specification of MASTER II telescope.

Item	Parameter	Number	Remark	Special name
Telescope (2 pieces)	Diameter	400 mm	Light-beam diameter	Hamilton system (Santel 400)
	Focus	1 000 mm	—	—
	Weight	50 kg	On each side	—
	Field of view	2 × 4 square degrees	For an Apogee AltaU16 type CCD camera	—
Mounting	Weight capacity	Up to 100 kg	German	NTM
	Maximum positioning speed	30 deg/s	—	—
Dome	Diameter	3.6 m	—	—
	Weight	500 kg	—	—
2 CCD cameras	Number of pixels	4K × 4K pix for each	—	—
	Pixel size	9 microns	—	—
	Image scale	1.84′′ per pix	—	—
Cloud Sensor	—	—	The Boltwood Cloud Sensor II	—
GPS	Accuracy of synchronization	100 microseconds	—	—
Server	RAM	8 Gb	—	—
	Processor	Xion 54XX	—	—
	HDDs	Rate 10Tb	—	—
Survey rate	—	480 sq. deg/h	—	—
Limiting magnitude for 1-min exposure	—	19 m	under optimum astroclimatic conditions	—

Our facility uses two lenses with the focal distances of 50 and 85 mm. The cameras allow continuous sky imaging with a minimum exposure of 150 milliseconds.

Figure 5: MASTER very wide-field camera.

3. Geographic Location of the Stations of the MASTER Network as of May 2009

The locations of the station sites were determined by two factors: (1) sites must be about ∼2 hours apart in longitude and (2) sites must provide minimum required infrastructure (power supply, Internet, warm room for servers). Such sites can usually be found at university observatories (Figure 6).

The participants to the project already include Moscow State University (Figure 7), Ural State University (Figure 8), Irkutsk State University, and Blagoveshchensk Pedagogical University. The network extends over seven hours in longitude, thereby ensuring virtually continuous 24-hour observations during winter seasons.

When deployed, the first step MASTER II telescope network will have the following parameters

(i) Total field of view—38 square degrees.

(ii) Survey rate—2000 square degrees per hour down to a limiting magnitude of 19-20.

(iii) Alert positioning speed-up to 30 degrees/s.

Table 2: Composition and specification of MASTER VWF camera.

Item	Parameter	Value	Remark	Special name
Lens (2 pieces)	Diameter	35.7 mm	Light-beam diameter	Nikor 50 f/1.4
	Focus	50 mm	—	—
	Field of view	1040 square degrees	For a CCD camera with a chip size of 24 × 36 mm	—
Lens (2 pieces)	Diameter	60.7 mm	Light-beam diameter	Zeiss-Nikor 85/1.4
	Focus	85 mm	—	—
	Field of view	432 square degrees	—	—
Mounting	Weight capacity	Up to 10 kg	Fork	Frictional
	Maximum positioning speed	6 deg/s	—	—
	Positioning accuracy	1 arcmin	—	—
Dome	Diameter	1 × 1.5 m	—	—
	Weight	30 kg	—	—
CCD cameras (2 pieces)	Number of pixels	12 Mpix	—	—
	Pixel size	9 microns	—	—
	Image scale	36″ per pix 20″ per pix	for f50 for f85	—
Limiting magnitude for 1-min exposure	—	11^m 13^m	for f50 for f85	—

Figure 6: Russian robotic network MASTER. The flags indicate the Russian contribution into gamma-ray burst's astrophysic. The yellow rectangles indicate planned sites of network stations and the indicators without rectangles introduce already equipped ones. From West to East: Moscow (MASTER I), Kislovodsk (MASTER II, MASTER VWF-4), Ekaterinburg (MASTER II), Novosibirsk (planed), Irkutsk (MASTER II in Tunka (made in November 2009) and VWF-2), Blagoveshchensk (MASTER-I, made in October 2009), and Ussuriysk (planned). The average annual number of clear nights is indicated near each site.

4. Expected Scientific Results

4.1. GRB Mystery. Observations of the prompt emission of gamma-ray bursts, which is determined by the physical processes in the central engine, are of fundamental importance for understanding the nature of these bursts (Lipunov and Gorbovskoy [7, 8]).

First and foremost, we expect that MASTER II telescopes will allow us to obtain multicolor photometric and polarimetric follow-up observations for alerts from gamma-ray

Figure 7: MASTER II (Kislovodsk, Sternberg Astronomical Institute, Moscow State University). Photo by A. Belinskiy.

Figure 8: MASTER II (Kourovka, near Ekaterinburg, Ural State University).

space observatories. We also plan to continue synchronous observations with very wide-field cameras. Recall that we have performed five synchronous observations of gamma-ray error boxes since November 2008 (Gorbovskoy et al. [9]).

4.2. Dark Energy. The first mass observations of type Ia supernovae showed (Reiss et al. [10]; Perlmutter S. et al. [11]) that the Universe expands with acceleration, which may be due to the so-called dark energy. This result follows from observations of several dozen supernovae. On the other hand, present-day search surveys miss most of the supernovae. The first computations of the velocities of explosions of cosmological supernovae performed by Jorgensen et al., [12] showed that the number of supernovae exploding in our Universe with magnitudes brighter than **m** can be described by the following formula:

$$N(< m) \sim 10^5 10^{\frac{3}{5(m-20)}} \text{yrs} - 1 \quad (15 < m < 22). \tag{1}$$

Note that without the correction for host-galaxy extinction 20^m corresponds to a redshift of $z \sim 0.2$-0.3, where the effect of cosmic energy of vacuum becomes quite appreciable.

This actually means that MASTER can discover several thousand supernovae annually and perform multicolor photometry of these objects.

5. Conclusion

A complete survey of the entire visible sky during a single night will allow to perform a number of tasks with no special observing plan (provided, naturally, proper coordination between the stations of the network):

(i) search for orphan flares,

(ii) search for exoplanets,

(iii) search for dangerous asteroids,

(iv) search for microlensing effects,

(v) search for and monitoring of space waste.

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References

[1] V. Lipunov, "Mobile astronomical systems of the telescope-robots (MASTER) near the Moscow," *Bulletin of the American Astronomical Society*, vol. 35, p. 766, 2003.

[2] V. M. Lipunov, A. V. Krylov, V. G. Kornilov, et al., "MASTER: the mobile astronomical system of telescope-robots," *Astronomische Nachrichten*, vol. 325, no. 6–8, pp. 580–582, 2004.

[3] V. M. Lipunov, V. G. Kornilov, A. V. Krylov, et al., "The master mobile astronomical system. Optical observations of gamma-ray bursts," *Astrophysics*, vol. 48, no. 3, pp. 389–399, 2005.

[4] V. M. Lipunov, V. G. Kornilov, A. V. Krylov, et al., "Optical observations of gamma-ray bursts, the discovery of supernovae 2005bv, 2005ee, and 2006ak, and searches for transients using the "MASTER" robotic telescope," *Astronomy Reports*, vol. 51, no. 12, pp. 1004–1025, 2007.

[5] N. Tyurina, V. Lipunov, V. Kornilov, et al., "MASTER prompt and follow-up GRB observations," http://arxiv.org/abs/0907.1036.

[6] B. Paczynski, "Astronomy with small telescopes," *Publications of the Astronomical Society of the Pacific*, vol. 118, no. 850, pp. 1621–1625, 2006.

[7] V. Lipunov and E. Gorbovskoy, "An extra long X-ray plateau in a gamma-ray burst and the spinar paradigm," *Astrophysical Journal*, vol. 665, no. 2, part 2, pp. L97–L100, 2007.

[8] V. M. Lipunov and E. S. Gorbovskoy, “Spinar paradigm and the central engine of gamma-ray bursts,” *Monthly Notices of the Royal Astronomical Society*, vol. 383, no. 4, pp. 1397–1412, 2008.

[9] E. Gorbovskoy, K. Ivanov, V. Lipunov, et al., “Transient detections and other real-time data processing from wide-field chambers MASTER VWF,” http://arxiv.org/abs/0907.1118.

[10] A. G. Riess, A. V. Filippenko, P. Challis, et al., “Observational evidence from supernovae for an accelerating universe and a cosmological constant,” *Astronomical Journal*, vol. 116, no. 3, pp. 1009–1038, 1998.

[11] S. Perlmutter, G. Aldering, G. Goldhaber, et al., “Measurements of Ω and Λ from 42 high-redshift Supernovae,” *Astrophysical Journal*, vol. 517, no. 2, pp. 565–586, 1999.

[12] H. E. Jorgensen, V. M. Lipunov, I. E. Panchenko, K. A. Postnov, and M. E. Prokhorov, “Evolution of supernova explosion rates in the universe,” *Astrophysical Journal*, vol. 486, no. 1, pp. 110–116, 1997.


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