

# Tracking and discovering asteroids

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(Accepted on 11.08.2011)

**Abstract.** We present the results from the participation of the Public Astronomical Observatory and Planetarium "Nicolaus Copernicus" in Varna, and Konstantin Preslavsky University of Shumen, in the international Killer Asteroid Project for tracking and searching of asteroids. In the observing time period August 2010 – May 2011 the Bulgarian participants found 43 asteroids: 6 already confirmed as new discoveries and 37 asteroids as preliminary discoveries.

**Key words:** asteroids, tracking, discovering

## Проследяване и откриване на астероиди

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Ние представяме резултатите от участието на Народната астрономическа обсерватория и планетариум "Николай Коперник" във Варна и Шуменския университет "Епископ Константин Преславски", в международния проект "Астероиди убийци" за проследяване и търсене на астероиди. За периода август 2010 – май 2011 г. ние намерихме 43 астероида: 6 вече потвърдени открития и 37 като предварителни открития.

## Introduction

In modern astronomy education, with the development of information technologies, distance and remote astronomical observations are made with great success. They give students the opportunity to participate in a real observational process and in the processing of real astronomical images. A significant role in increasing the quality of astronomy education in schools and universities play professional astronomical institutions and organizations. Interesting observational programs and projects, targeted towards high-school and university students, are developed and carried out on an international level. The basis of this collective, between professional astronomers and astronomy teachers, education, is the more and more popular here "project" method of education.

One of the most interesting for students topics in the astronomy curriculum is the one about small bodies in the Solar System. A particular interest for young people and astronomers pose a group of asteroids whose orbits cross the Earth's orbit, or are inside the Moon's orbit. Different scientific observational campaigns and programs are organized to track close and dangerous objects, and to search for asteroids. One of these programs, which is funded by NASA, is targeted towards high-school and university students, who are given the opportunity to track and search for asteroids. The main goal is for them to acquire astronomical knowledge, to get to know the work

of professional astronomers as they learn how to process astronomical images, obtained using small telescopes in the USA.

The international project for searching for and tracking asteroids is organized by the Astronomical Research Institute, established in 2002. The team of this organisation aims to popularize, develop and aid research in the field of astronomy, to offer knowledge, resources and means to high-school and university students, and high-school teachers. A long-term project for high-school and university students is thus developed, which offers the opportunity for observations and discoveries of objects from the main belt between Mars and Jupiter, and of close and dangerous asteroids.

The participation of Bulgarian students started in 2008. The students attend the astronomy courses at the Public Astronomical Observatory and Planetarium "Nicolaus Copernicus" in Varna, led by Dr. Veselka Radeva. The participation of students studying Astronomy at Konstantin Preslavsky University of Shumen began in 2010. Until now, 240 schools from 26 countries and 4 continents have participated in the project. Since October 2006, until now, students have discovered more than 250 asteroids from the main belt; 1800 observations of close and dangerous asteroids have been made; and there have been 300 confirmations of close asteroids.

## **1 Results from the Bulgarian participation in the international Killer Asteroid Project for tracking and searching of asteroids**

### **1.1 Organisation of the work on observational campaigns**

The work on tracking and searching for asteroids is organized in 45 daily campaigns. The campaigns are of two types: tracking of close and dangerous asteroids, and searching for new asteroids. Up to 20 teams of students participate in each observing campaign. In the specially created for the project observatory, in Westfield, Illinois, USA, every clear night is used to make observations with a 24 inch and a 32 inch telescope (Fig. 1).

These telescopes are used by the famous comets discoverer Robert Holmes. After preliminary image processing, they are uploaded on the individual for every team website. The astronomical software Astrometrica is used for the processing, with which the already discovered asteroids are identified, and new asteroids are discovered; their equatorial coordinates (Right Ascension and Declination) are determined, with accuracy of RA and Dec up to  $0.3''$ . Reports with the results are prepared and sent for confirmation to the Head of the observing campaign. The images have to be processed by the students, and the results sent to the organizers within 48 hours of being received.

### **1.2 Stages in the work on tracking and searching of asteroids**

The work of student teams on the project is organized as instruction using the "project" method. The students form teams, which undergo preliminary theoretical preparation. It includes a series of lectures and practical exercises on the topics: asteroids - nature and motion; orbital elements; work with star maps and catalogues; and astrometric software for image processing. After

learning the theoretical material, and acquiring skills in working with astronomical software, students are ready to work on the project. The organization of work on tracking and searching for asteroids includes the following stages:



**Fig. 1.** The telescopes for tracking and searching of asteroids at the Observatory. The images are acquired by the Astronomical Observatory of the Astronomical Research Institute, USA.

First stage: Identification of astronomical images using star catalogues. The following astrometric catalogues are used for this purpose: USNO-SA 2.0; USNO-A2.0; USNO-B 1.0; UCAC 2; UCAC 3; NOMAD; CMC-14; PPMXL.

Using Astrometrica the following procedures are followed: recording a list of all stars on the images; arranging the images by date and hour; connecting to a star catalogue online; comparing the recorded stars with data from the star catalogue in order to create a coordinate system for "the best match"; analyzing the difference between the position and magnitude of stars from the images and from the catalogue; identifying the stellar fields of the images with the catalogue fields. After the comparison, 200 reference stars are chosen, achieving accuracy of  $dRA$  and  $dDec$  of less than  $0.10''$ .

Second stage: Finding moving objects and determining their coordinates.

Automatic mode: Astrometrica identifies moving objects and shows them in the window for checking.

Manual mode: The images are "blinked" to find moving objects. After their identification, their coordinates are measured in RA and Declination.

Third stage: A report with the results is prepared in the format required by the Minor Planet Center. The results are checked in the software, provided by the project, after which a check is done in the database of the Minor Planet Center in Harvard.

For the time period August 2010-May 2011 the Bulgarian team of students, led by Dr. Veselka Radeva, participated in five observing campaigns. 200 packages of astronomical images of asteroids were processed, and the equatorial coordinates of more than 284 asteroids were determined. These are mostly asteroids from the main belt, found between Mars and Jupiter, for which clarification of the orbital elements was needed. Newly found close and dangerous asteroids were observed. Among them the most dangerous asteroid was 2010 TQ19, observed on 08.10.2010. This asteroid passed at a distance from the Earth of 9.6 Earth-Moon distances (1 Earth-Moon distance = 384 401 km); its size is only 37 meters and its magnitude at the time of closest approach was  $23^m$ .

Orbital Elements at Epoch 2455360.5 (2010-Jun-13.0) TDB			
Reference: MPO196781 (heliocentric ecliptic J2000)			
Element	Value	Uncertainty (1-sigma)	Units
e	0.3122930	n/a	
a	2.6822304	n/a	AU
q	1.8445886	n/a	AU
i	7.50939	n/a	deg
node	152.63454	n/a	deg
peri	162.57390	n/a	deg
M	324.18207	n/a	deg
t <sub>p</sub>	2455520.1395574	n/a	JED
	(2010-Nov-19.63955740)		
period	1604.5103857	n/a	d
	4.39	n/a	yr
n	0.22436751	n/a	deg/d
Q	3.5198722	n/a	AU

Fig. 2. The orbital elements of the new asteroid 2010 MR4.

Astrometric observations of asteroids are determined by Sunay Ibryamov (University of Shumen), Borislav Nedelchev (Public Astronomical Observatory and Planetarium (PAOP)-Varna), Stefania Gospodinova (PAOP-Varna), Tsanko Yordanov (PAOP-Varna), Julien Keremedzhiev (PAOP-Varna), Anastasia Antonova (PAOP-Varna), Ivan Popov (PAOP-Varna), Nedelcho Laskov (PAOP-Varna), Apostol Deludis (PAOP-Varna), Veliko Kolev (NAOP-Varna), Teodora Atanasova (University of Shumen) and Desislava Ivanova (University of Shumen).

After checking the astrometric results in the database of the Minor Planet Center, the preliminary discovery of new objects was made. This means that

**Table 1.** Preliminary asteroid discoveries

No	Preliminary Discovery	Discoverers	School	Date
1	TOV3M8	S. Ibryamov, V. Radeva	University of Shumen	25.01.2011
2	TOV3MC	S. Ibryamov, V. Radeva	University of Shumen	25.01.2011
3	TOV3MD	S. Ibryamov, V. Radeva	University of Shumen	25.01.2011
4	TOV3NX	S. Ibryamov	Student Astronomical Society of Shumen Univ.	31.01.2011
5	TOV3NV	S. Ibryamov	Student Astronomical Society of Shumen Univ.	31.01.2011
6	TOV3XQ	V. Radeva, A. Antonova, A. Deludis	High School of Natural Sciences	04.02.2011
7	TOV30R	S. Ibryamov, V. Radeva	University of Shumen	10.02.2011
8	TOV30U	V. Radeva	The Language School "Frederic Joilot Curie"	10.02.2011
9	TOV3Q0	A. Antonova, V. Radeva	The Language School "Frederic Joilot Curie"	01.03.2011
10	TOV3QY	A. Antonova, V. Radeva	The Language School "Frederic Joilot Curie"	02.03.2011
11	TOV3SN	S. Ibryamov	Student Astronomical Society of Shumen Univ.	03.03.2011
12	TOV3SO	B. Nedelchev, A. Antonova, V. Radeva	High School of Natural Sciences	03.03.2011
13	TOV3XY	S. Ibryamov, V. Radeva	University of Shumen	02.04.2011
14	TOV3YQ	V. Radeva, Ts. Yordanov	First Language School	06.04.2011
15	TOV3ZY	S. Ibryamov, B. Nedelchev, V. Radeva	University of Shumen	21.04.2011
16	TOV3ZF	V. Radeva	First Language School	21.04.2011

they have a small number of determined orbital positions and need additional observations to determine their orbits with certainty. In Table 1 we present the preliminary asteroid discoveries.

**Table 2.** New asteroids

No	Asteroid	Discoverers	Date	Orbital elements
1	2010 MR4	B. Nedelchev, Ts. Yordanov, V. Radeva	18.06.2010	(see Fig. 2)
2	2011 EW5	Ts. Yordanov, J. Keremedchiev, V. Radeva	01.03.2011	Accurate determination in process
3	2011 HC60	B. Nedelchev, V. Radeva	30.04.2011	Accurate determination in process

Some of the preliminary discoveries were tracked and confirmed by other observers. After the tracking observations, the new objects were classified by the Minor Planet Center as a regular discovery and the asteroids were named. Table 2 presents the discovered new asteroids. They are from the main belt, between Mars and Jupiter.

Figure 2 present the orbital elements of the new asteroid 2010 MR4.

## 2 Results from the Bulgarian participation in the Pan-STARRS Asteroid Search Campaign

### 2.1 Work organization

The observations in the Pan-STARRS (The Panoramic Survey Telescope and Rapid Response System) campaign for discovering new celestial objects are made with the new telescope Pan-STARRS 1 (Fig. 3) for space defense, at Haleakala, Hawaii. This telescope is a unique 1.8 meter instrument, that has the largest gigapixel CCD in the world (Fig. 4) and is capable of an extremely fast scan of the entire sky, over the course of several hours.

Sunay Ibryamov from University of Shumen was invited to participate in the observing campaign for the time period 28 March - 13 May 2011. 16 teams from the whole world participate in the campaign, and each team consists of two team-members from different countries. The team of University of Shumen is the only one from Bulgaria, participating in the Pan-STARRS campaign. The partner-team to that of University of Shumen is a team from the Department "Astronomy and Space Sciences" from Istanbul University in Turkey. The team from Istanbul University was instructed by Sunay Ibryamov, who also leads the Bulgarian team.

Three of the preliminary discoveries were tracked and confirmed by other observers, and officially recognized as discoveries by the Minor Planet Center in Harvard. The new asteroids have the temporary identifications 2011 FY16, 2011 FU88 and 2011 HK35. After calculation of the exact orbital parameters, according to the rules of the International Astronomical Union, the discoverer has the right to suggest names for the discovered objects. Table 4 presents the discovered new asteroids. They are from the main asteroid belt, between Mars and Jupiter.



**Fig. 3.** The Observatory Pan-STARRS 1, *Image: Rob Ratkowski*

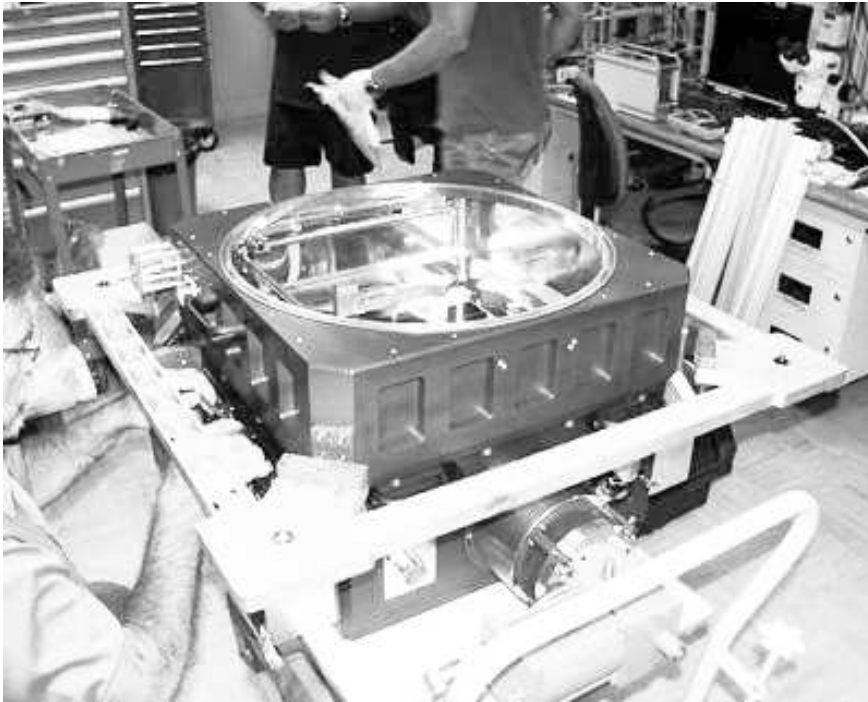
**Table 3.** Preliminary asteroid discoveries

No	Preliminary Discovery	Discoverer	School	Date
1	TVPS0C7	S. Ibryamov	University of Shumen	25.03.2011
2	TVPS0C8	S. Ibryamov	University of Shumen	25.03.2011
3	TVPS0CA	S. Ibryamov	University of Shumen	25.03.2011
4	TVPS0CB	S. Ibryamov	University of Shumen	25.03.2011
5	TVPS0G0	S. Ibryamov	University of Shumen	31.03.2011
6	TVPS0G1	S. Ibryamov	University of Shumen	31.03.2011
7	TVPS0G3	S. Ibryamov	University of Shumen	31.03.2011
8	TVPS0G4	S. Ibryamov	University of Shumen	31.03.2011
9	TVPS0G5	S. Ibryamov	University of Shumen	31.03.2011
10	TVPS0G6	S. Ibryamov	University of Shumen	31.03.2011
11	TVPS0G8	S. Ibryamov	University of Shumen	31.03.2011
12	TVPS0IT	S. Ibryamov	University of Shumen	23.04.2011
13	TVPS0IU	S. Ibryamov	University of Shumen	23.04.2011
14	TVPS0IV	S. Ibryamov	University of Shumen	23.04.2011
15	TVPS0IW	S. Ibryamov	University of Shumen	23.04.2011
16	TVPS0L4	S. Ibryamov	University of Shumen	30.04.2011
17	TVPS0L5	S. Ibryamov	University of Shumen	30.04.2011
18	TVPS0L6	S. Ibryamov	University of Shumen	30.04.2011
19	TVPS0L7	S. Ibryamov	University of Shumen	30.04.2011
20	TVPS0L8	S. Ibryamov	University of Shumen	30.04.2011
21	TVPS0L9	S. Ibryamov	University of Shumen	30.04.2011

## 2.2 Results from the Bulgarian participation in the Pan-STARRS campaign

The team from University of Shumen, participating in the Pan-STARRS campaign, for the time period 28 March - 13 May 2011, processed 32 data

packages and made 21 preliminary discoveries of asteroids. Table 3 presents the preliminary discoveries of asteroids by the Bulgarian team, for the Pan-STARRS campaign.



**Fig. 4.** The gigapixel camera, mounted on the Pan-STARRS 1 telescope, *Image: <http://pan-starrs.ifa.hawaii.edu>*

**Table 4.** New asteroids

No	Asteroid	Discoverer	Discovered Date	Confirmed Date	Orbital elements
1	2011 FY16	S. Ibryamov	25.03.2011	31.03.2011	(see Fig. 5)
2	2011 FU88	S. Ibryamov	25.03.2011	11.04.2011	(see Fig. 6)
3	2011 HK35	S. Ibryamov	23.04.2011	30.04.2011	Accurate determination in process

Figures 5 and 6 present the orbital elements of the new asteroids 2011 FY16 and 2011 FU88.



Orbital Elements at Epoch 2455800.5 (2011-Aug-27.0) TDB Reference: MPO196449 (heliocentric ecliptic J2000)			
Element	Value	Uncertainty (1-sigma)	Units
e	0.1511370	n/a	
a	2.6930456	n/a	AU
q	2.2860268	n/a	AU
i	7.08650	n/a	deg
node	219.94378	n/a	deg
peri	2.73174	n/a	deg
M	8.34233	n/a	deg
t <sub>p</sub>	2455763.0933470 (2011-Jul-20.59334700)	n/a	JED
period	1614.2246915	n/a	d
	4.42	n/a	yr
n	0.22301728	n/a	deg/d
Q	3.1000644	n/a	AU

Fig. 5. The orbital elements of the new asteroid 2011 FY16

Orbital Elements at Epoch 2455640.5 (2011-Mar-20.0) TDB Reference: MPO199010 (heliocentric ecliptic J2000)			
Element	Value	Uncertainty (1-sigma)	Units
e	0.2073329	n/a	
a	3.0618997	n/a	AU
q	2.4270672	n/a	AU
i	4.11338	n/a	deg
node	267.36265	n/a	deg
peri	328.77226	n/a	deg
M	326.61376	n/a	deg
t <sub>p</sub>	2455821.9888272 (2011-Sep-17.48882721)	n/a	JED
period	1956.9732256	n/a	d
	5.36	n/a	yr
n	0.18395755	n/a	deg/d
Q	3.6967322	n/a	AU

Fig. 6. The orbital elements of the new asteroid 2011 FU88

## Conclusion

The Bulgarian high-school and university students, participating in the International campaign for tracking and searching for asteroids, work very responsibly and have high quality production. The opportunity offered to young people to be an active part of the astronomical research process, motivates them in their personal development and expansion of their astronomical knowledge. The consideration of every activity in the work process, the discussion of encountered problems, the self-check of results and their analysis -

are important steps in the intricate process of scientific research. The personal engagement and desire to accumulate more knowledge and skills in the work process leads to very good results in the astronomical education process.

The international project for tracking and searching for asteroids provokes justified great interest among Bulgarian students and teachers. The successful participation of students is to a large degree due to the good preparation of teacher-leaders of the teams and the preparedness at any time to process, verify and analyze the results of students. Teams from the Mathematical and Language schools in Shumen participate successfully in the project. The participation of Bulgarian teams in the project received a high rating by the leaders of the program and between 21 October and 5 December 2011 the Pan-Bulgarian Asteroid Search Campaign started, in which 10 Bulgarian teams will participate. The Bulgarian observing campaign will give the opportunity to many students and teachers over the course of 45 days to process tens of astronomical images, to track dangerous and close asteroids, and to make their discoveries.

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