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Studies of NEOs as a task for small telescopes

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Abstract. The decades of successful research at the high-altitude observatory Terskol in the Northern Caucasus have yielded new data and findings in the field of monitoring and studies of NEOs. Facilities of the Terskol Observatory, which include optical telescopes with diameters up to 2 m, their instrumentation (high- and low-resolution spectrometers, high-speed photometers, CCDs, etc.), have been heavily used for follow-up astrometry, photometry and spectroscopy of Earth-approaching asteroids and comets. In this paper, advances in studies of NEOs achieved in the last years at Terskol are presented.

Key words: asteroids: astrometry, photometry, spectroscopy – asteroid spectral types – NEOs

1. Introduction

Beginning in 1996, the facilities of the Terskol Observatory (the Northern Caucasus, 3100 m asl) contribute significantly to achieving important results in the following fields of research: precise astrometry and photometry of Solar System bodies, monitoring of NEOs and space debris, high-speed photometry of variable stars, high-resolution spectroscopy of interstellar clouds, search for optical afterglow of gamma ray bursts, etc. (Tarady *et al.*, 2010).

The available small and medium-sized telescopes (Zeiss-2000 and Zeiss-600, as well as Celestron 11″ and Meade 14″) provide good enough opportunities especially for astrometric, photometric, and spectroscopic observations of Earth-approaching asteroids and comets. Many advances in this field came from the development and use of specific instruments and techniques. Successful scientific operations of the well-equipped small telescopes made over the past years have also proven their usefulness for long-term observational programmes.

2. Science objectives

2.1. Astrometry and photometry of near-Earth objects

Since the early 2000s, observational data sets of about 300 asteroids and comets (with V magnitudes down to 21^{m}) have been collected at Terskol. High-accuracy

photometry has been used for a number of asteroids to obtain their lightcurve amplitudes, as well as to determine their rotation periods.

Precise astrometric data have been routed directly to the IAU Minor Planet Center for analysis (www.minorplanetcenter.net). In 2003–2013, positions of more than 200 NEOs were detected. Accuracy achieved in positions of NEOs ($17^{\rm m}-19^{\rm m}$) is about $0\farcs1$–$0\farcs7$.

Long-term astrometric observations of NEOs allowed us to sufficiently well calculate their orbits and to improve predictions about close encounters with the Earth. In 2012–2013, a special attention was given to the monitoring of potentially hazardous asteroids 4179 Toutatis, 99942 Apophis, and 2013 TV135. Some of these data can be found at http://newton.dm.unipi.it/neodys/ as "Obs & residuals" of the Terskol Observatory (code B18).

2.2. Spectroscopy of near-Earth objects

Some progress in studies of near-Earth asteroids has been made by using a slitless low-resolution UBVR spectrograph at the Zeiss-600 telescope. The spectrograph constructed has a resolution of $R \approx 100$ in the vicinity of 4800 Å and provides a moderate signal-to-noise ratio for objects up to magnitude $16^{\rm m}$ (Zhilyaev *et al.*, 2012).

Asteroids have been observed down to V magnitude of $14^{\rm m}$, with individual exposure times of 10–30 s; their spectra have been recorded over the wavelength range from 300 to 900 nm. Appropriate software developed has been applied to derive asteroids properties from spectrophotometric observations.

Special attention is given to the taxonomic classification of near-Earth asteroids because in most cases their physical properties are previously unknown. We obtained the asteroids spectral types by using a taxonomic classification technique defined in Tholen (1984), Barucci *et al.* (1987), and Tedesco *et al.* (1989).

The taxonomy introduced in Tedesco *et al.* (1989) uses the minimum number of observable parameters necessary to account for the physical processes being classified, namely, the strengths of the two principal absorption features found in asteroid visual-wavelength-range spectra and the albedo. Specifically, the $U-V$ color index (0.36–0.55 μm) is a measure of the strength of the short-wavelength absorption feature, while the $v-x$ color index (0.55–0.85 μm) provides a measure of the strength of the long-wavelength feature.

According to this technique, three parameters (i.e. $U-V$ and $v-x$ color indices and visual geometric albedo) were calculated and used to determine taxonomic classes of PHAs. We obtained $U-V$ and $v-x$ colors through mathematical convolution of our spectra with the photometric transmission curves of Johnson and ECAS filters, respectively (the ECAS data set can be found on the website http://sbn.psi.edu/pds/resource/ecas.html). From observations of standard stars, magnitudes and color indices of asteroids were corrected for atmospheric extinction. For instance, color indices computed for asteroids

2007 PA8 and 2012 QG42 are ($U - V = 1.34 \pm 0.05$, $v - x = 0.10 \pm 0.04$) and ($U - V = 1.3 \pm 0.3$, $v - x = 0.1 \pm 0.2$), respectively. Furthermore, spectra of solar-type stars were used to obtain the relative reflectance spectrum for each asteroid.

Figure 1 depicts the relative reflectance spectra of asteroids 2007 PA8, 2012 QG42, 4179 Toutatis, and 1998 QE2, which were observed in 2012–2013. Analyses of data obtained have allowed the first three objects to be classified as the S-type; asteroid 1998 QE2 was placed in the C-class.

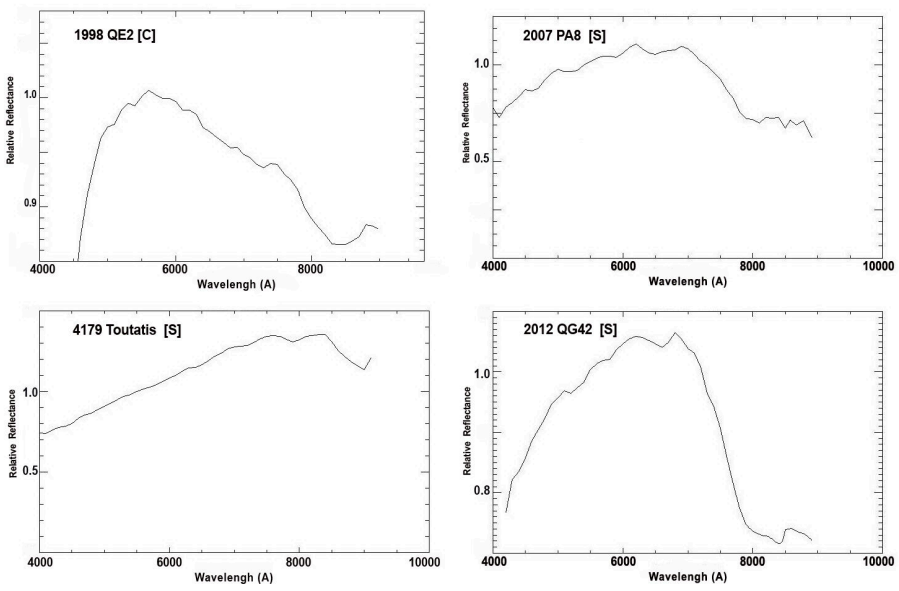

Figure 1. Relative reflectance spectra of asteroids 1998 QE2, 2007 PA8, 4179 Toutatis, and 2012 QG42.

3. Conclusions

In consideration of the importance of finding and studying Earth-approaching objects, which can represent an impact hazard to our planet, one of the priorities of ground-based astronomy must be assigned to discovery and monitoring of these objects.

We have come a long way installing new instruments and developing new techniques in order to provide observational data of sufficient quality. Today, the telescopes at the Terskol Observatory have been successfully used for follow-up astrometry, photometry, and spectroscopy of Earth-approaching asteroids and

comets. Special observing and data-analysis techniques developed have been applied to determine the spectral type, relative reflectance and other parameters of asteroids.

Our results and findings in this field of research have demonstrated that small and medium-sized telescopes can constitute a major contribution to monitoring and investigation of NEOs.

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