

Studies of NEOs as a task for small telescopes

V. Tarady, O. Sergeev, M. Andreev, V. Godunova, **V. Reshetnyk**

ICAMER Observatory, NASU, 27 Zabolotnoho St., 03680 Kyiv, Ukraine V_Godunova@bigmir.net

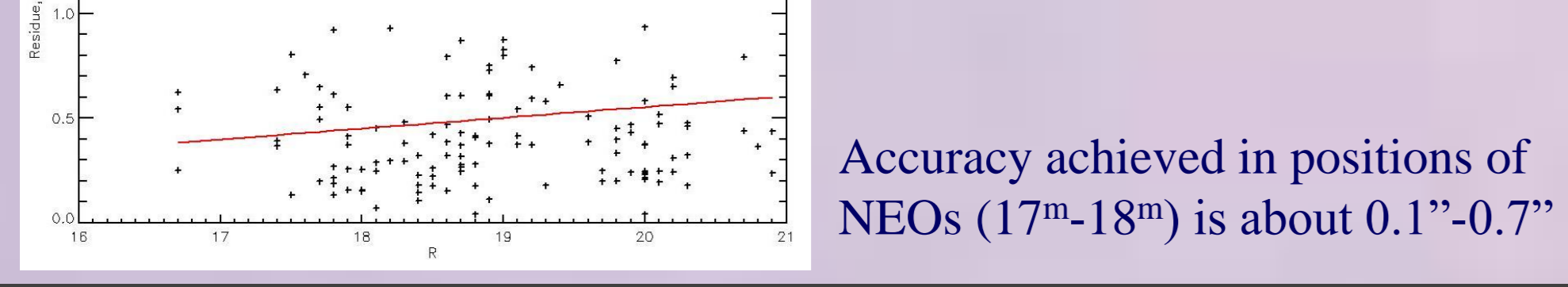
Beginning in 1996, the facilities of the Terskol Observatory (the Northern Caucasus, 3100 m asl) have been heavily used for studies of Solar System small bodies. The available small and medium-sized telescopes (Zeiss-2000 and Zeiss-600, as well as Celestron 11" and Meade 14") provide good enough opportunities for long-term astrometric, photometric, spectroscopic, and other observations of these objects. In addition, many advances in this field came from the development and use of specific instruments and techniques [1]. A special attention is given to the monitoring and study of potentially hazardous objects - Earth-approaching asteroids and comets.

Astrometry

Precise astrometric data acquired during observations of near-Earth objects at Terskol have been routed directly to the IAU Minor Planet Center for analysis. In 2003-2013, positions of more than 200 NEOs were detected.

www.minorplanetcenter.net

Target	Date	MPEC Circulars
Comet C/2011 R1	03 Sep 2011	MPEC 2011-R20: Comet C/2011 R1 (McNaught)
Comet P/2011 R2	03 Sep 2011	MPEC 2011-R21: Comet P/2011 R2 (PanStarrs)
2011 R21	03 Sep 2011	MPEC 2011-R22: 2011 R21
Comet P/2011 R3	03 Sep 2011	MPEC 2011-R23: Comet P/2011 R3 (PanStarrs)
2011 R23	03 Sep 2011	MPEC 2011-R24: 2011 R23
2004 RT109	18 Sep 2011	MPEC 2011-S07: 2004 RT109
2011 S07	18 Sep 2011	MPEC 2011-S08: 2011 S07
2000 AB6	19 Sep 2011	MPEC 2011-S10: 2000 AB6
2011 S10	19 Sep 2011	MPEC 2011-S11: 2011 S10
2011 S15	19 Sep 2011	MPEC 2011-S12: 2011 S15
2011 S16	20 Sep 2011	MPEC 2011-S13: 2011 S16
2011 S16	20 Sep 2011	MPEC 2011-S14: 2011 S16
2011 S25	20 Sep 2011	MPEC 2011-S15: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S16: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S17: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S18: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S19: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S20: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S21: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S22: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S23: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S24: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S25: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S26: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S27: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S28: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S29: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S30: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S31: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S32: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S33: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S34: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S35: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S36: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S37: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S38: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S39: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S40: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S41: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S42: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S43: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S44: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S45: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S46: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S47: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S48: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S49: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S50: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S51: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S52: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S53: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S54: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S55: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S56: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S57: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S58: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S59: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S60: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S61: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S62: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S63: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S64: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S65: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S66: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S67: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S68: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S69: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S70: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S71: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S72: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S73: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S74: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S75: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S76: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S77: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S78: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S79: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S80: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S81: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S82: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S83: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S84: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S85: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S86: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S87: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S88: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S89: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S90: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S91: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S92: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S93: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S94: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S95: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S96: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S97: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S98: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S99: 2011 S25
2011 S25	20 Sep 2011	MPEC 2011-S00: 2011 S25

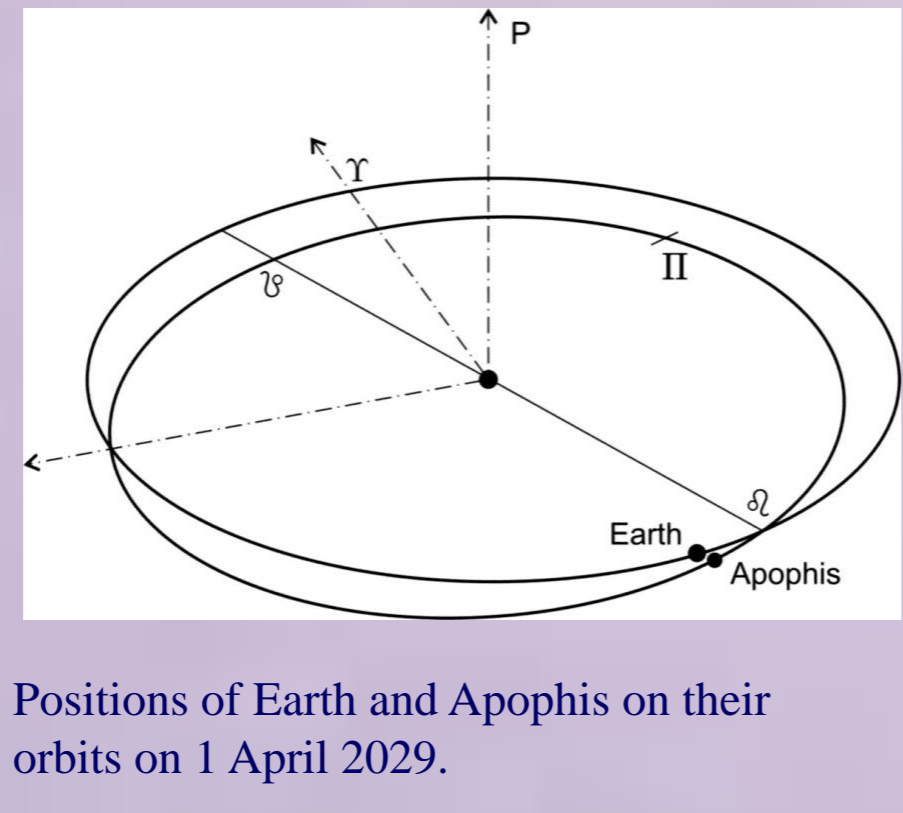


NEODYS-2

<http://newton.dm.unipi.it/neodys>

Designation	Type	Date	Right Ascension	Declination	Apparent Magnitude	Distance (AU)	Velocity (km/s)	Lead & Lag (h)	Lead & Lag (km)	Lead & Lag (Earth radii)
2000000000	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC01	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC02	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC03	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC04	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC05	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC06	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC07	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC08	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC09	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC10	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC11	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC12	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC13	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC14	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC15	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC16	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC17	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC18	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC19	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000
2011MPC20	C	2011-10-06	10.000000	00.000000	15.000000	1.000000	0.000000	0.000000	0.000000	0.000000

Long-term astrometric observations of NEOs allow one to sufficiently well calculate their orbits and to improve predictions about close encounters with Earth. Especially in 2012-2013, a special attention was given to the monitoring of potentially hazardous asteroids 4179 Toutatis and 99942 Apophis.



Spectroscopy

Spectra of asteroids have been obtained by using a low-resolution imaging spectrograph attached to the Zeiss-600 telescope (Fig.1). Objects were observed down to V magnitude of 15, with individual exposure times of 10-30 s; their spectra were recorded over the wavelength range from 300 to 900 nm.

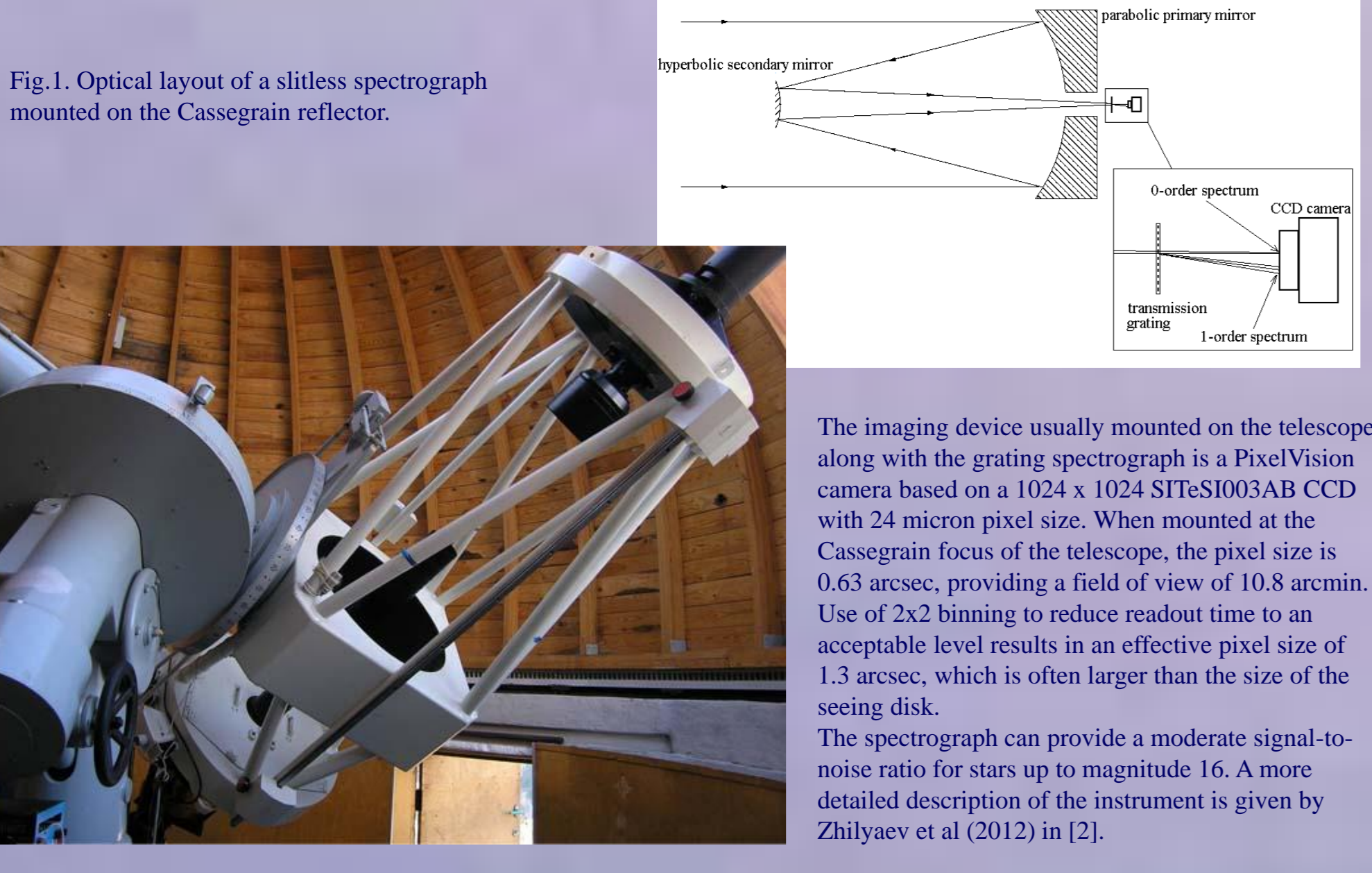


Figure 2 shows CCD images of asteroid 2012 QG42, which were taken using the low-resolution spectrograph; it demonstrates asteroid's and stars spectra within the field of view; bad pixels and cosmic ray hits have been removed.

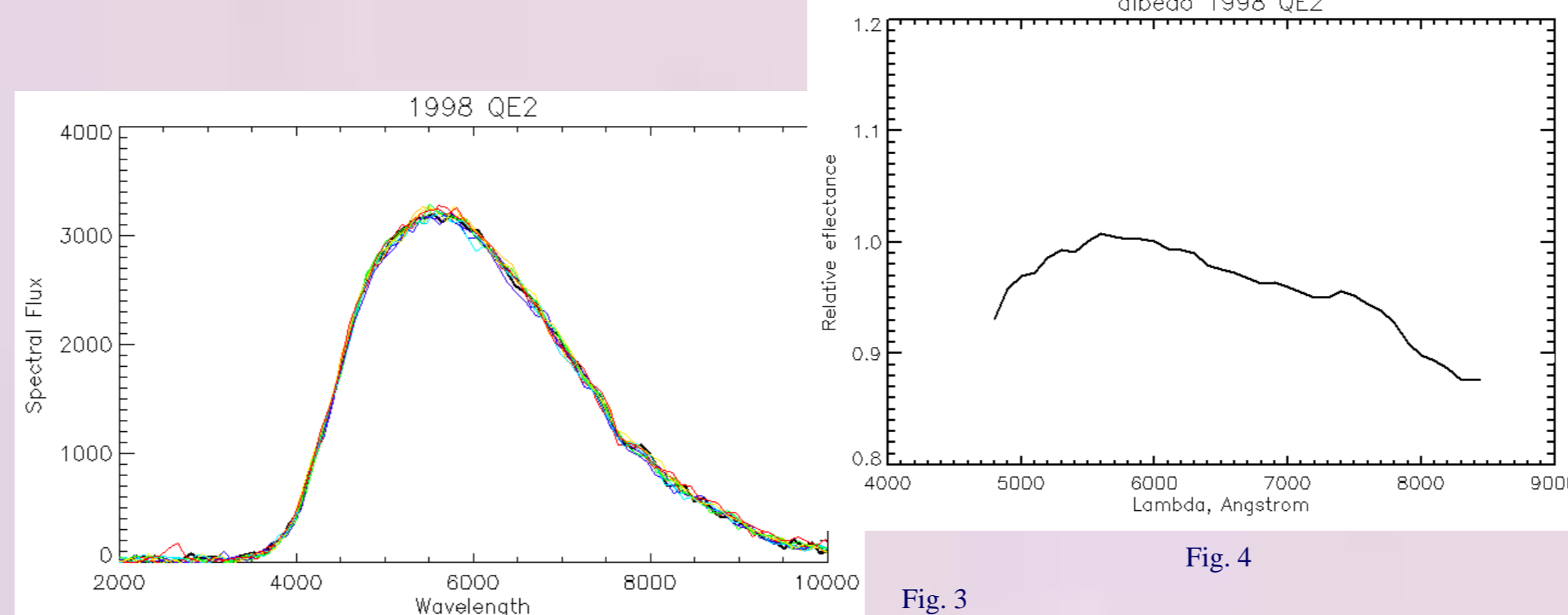
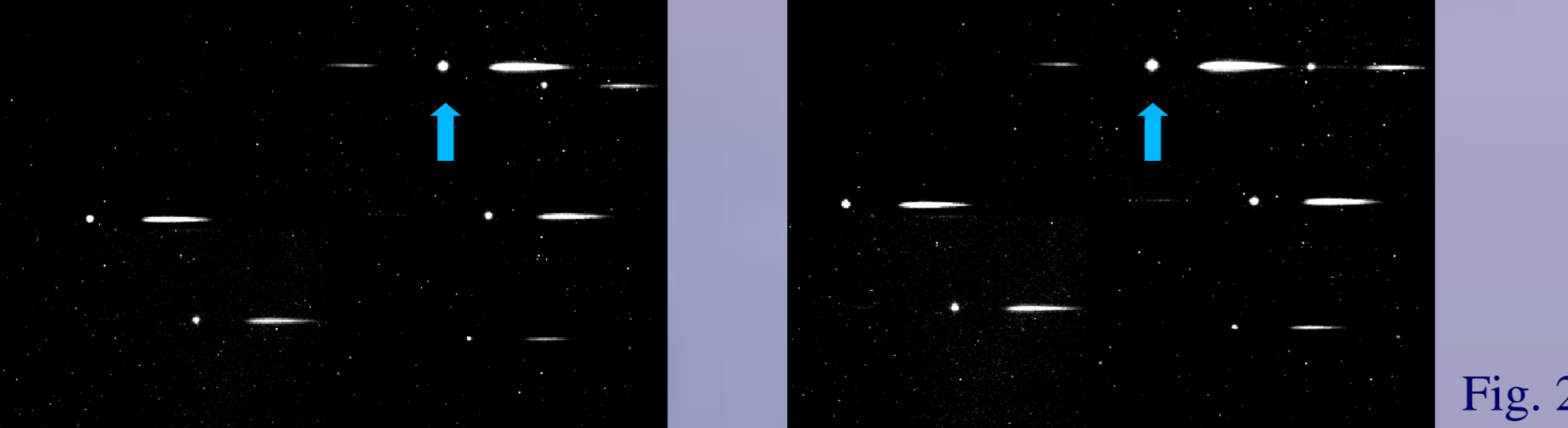
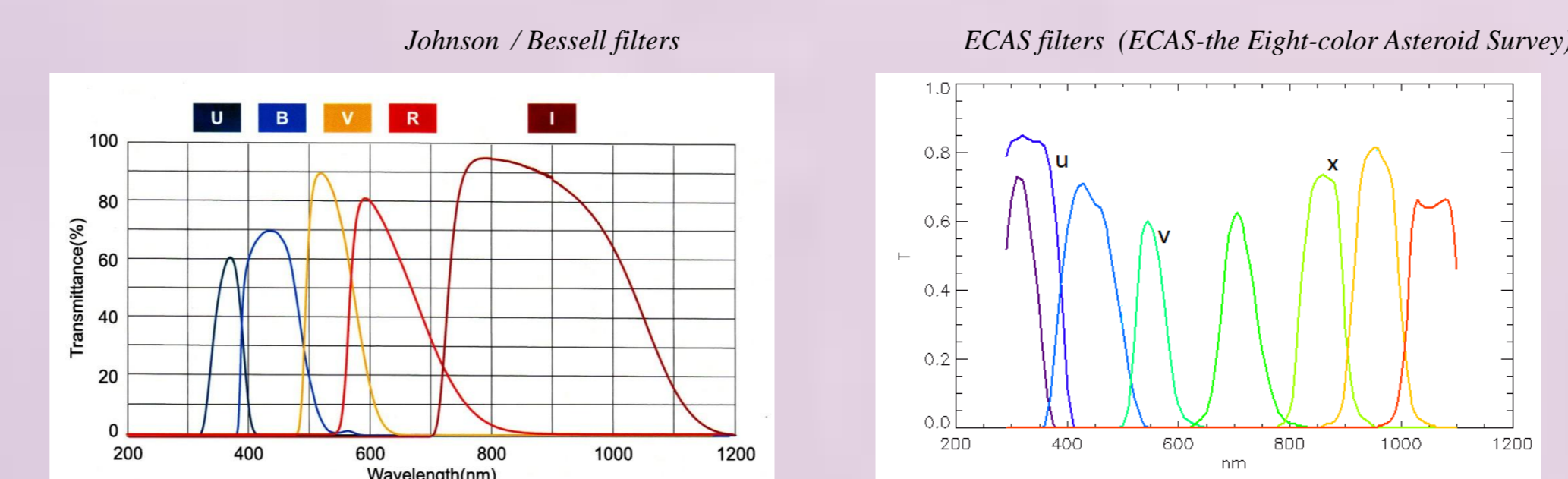


Figure 3 depicts the low-resolution spectra of asteroid 1998 QE2 extracted from a series of CCD images, which were taken on 4 June 2013. The relative reflectance spectrum calculated (Fig. 4) allows one to place this asteroid in the C-class

Appropriate observing and data-analysis techniques developed have been applied to derive asteroid's properties from spectrophotometric observations. A special attention was given to the taxonomic classification of Earth-approaching asteroids because in most cases their physical properties are previously unknown.

Light curves of asteroids were obtained using the convolution of observed spectra with photometric filters transmission curves (s. below).



From observations of standard stars, extinction-corrected magnitudes and color indices of asteroid were calculated. Furthermore, spectra of solar-type stars were used to obtain the relative reflectance spectra for each asteroid.

In 2012-2013, observations of 2007 PA8, 2012 QG42, 4179 Toutatis, 1998 QE2, 2002 OD20, and other PHAs were performed.

Analyses of the spectra obtained have allowed the majority of these objects to be classified as S-type (Fig. 4, 6).

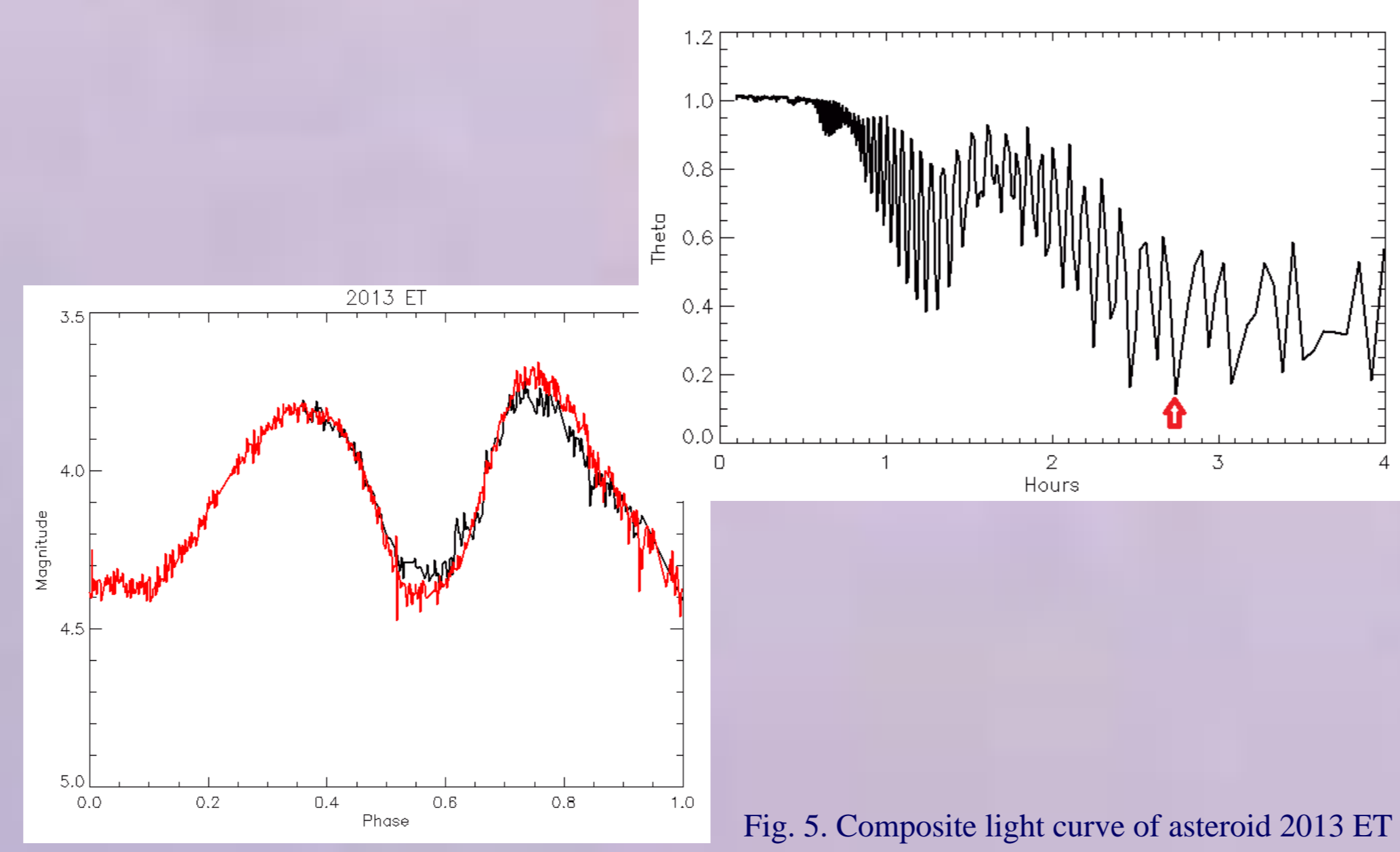
Photometry

Starting in 1996, precision photometric measures of many near-Earth asteroids have been carried out at Terskol. The revealed light curves allow one to calculate lightcurve amplitude and rotation period of asteroids.

2013 ET

It was discovered by the Catalina Sky Survey on March 3, 2013. This asteroid made a very close approach (2.5 lunar distances) to Earth on March 9, 2013.

We have carried out photometric observations of 2013 ET on March 6-7 and 7-8, 2013 when it reached a magnitude of 15.7 and 15.1, respectively. From these observations, a rotational period of ~2.7 h was determined.



CONCLUSIONS

Small- and medium-aperture telescopes, equipped with CCD cameras and additional instruments, still provide good enough opportunities for long-term astrometric, photometric, polarimetric, and other observations, especially for follow-up photometry and spectroscopy of near-Earth objects.

The telescopes Zeiss-2000 and Zeiss-600 at the Terskol Observatory have been successfully used for follow-up astrometry and spectroscopy of Earth-approaching asteroids and comets. Some progress in studying of NEOs has been made by using a slitless UBVR spectrograph at the 60-cm telescope. Appropriate data-analysis techniques developed have been applied to determine spectral classes, relative reflectance and other parameters of asteroids.

To date, a number of NEOs were classified regards to their spectral types. Moreover, spectral properties calculated agree good enough with those obtained by other authors.

