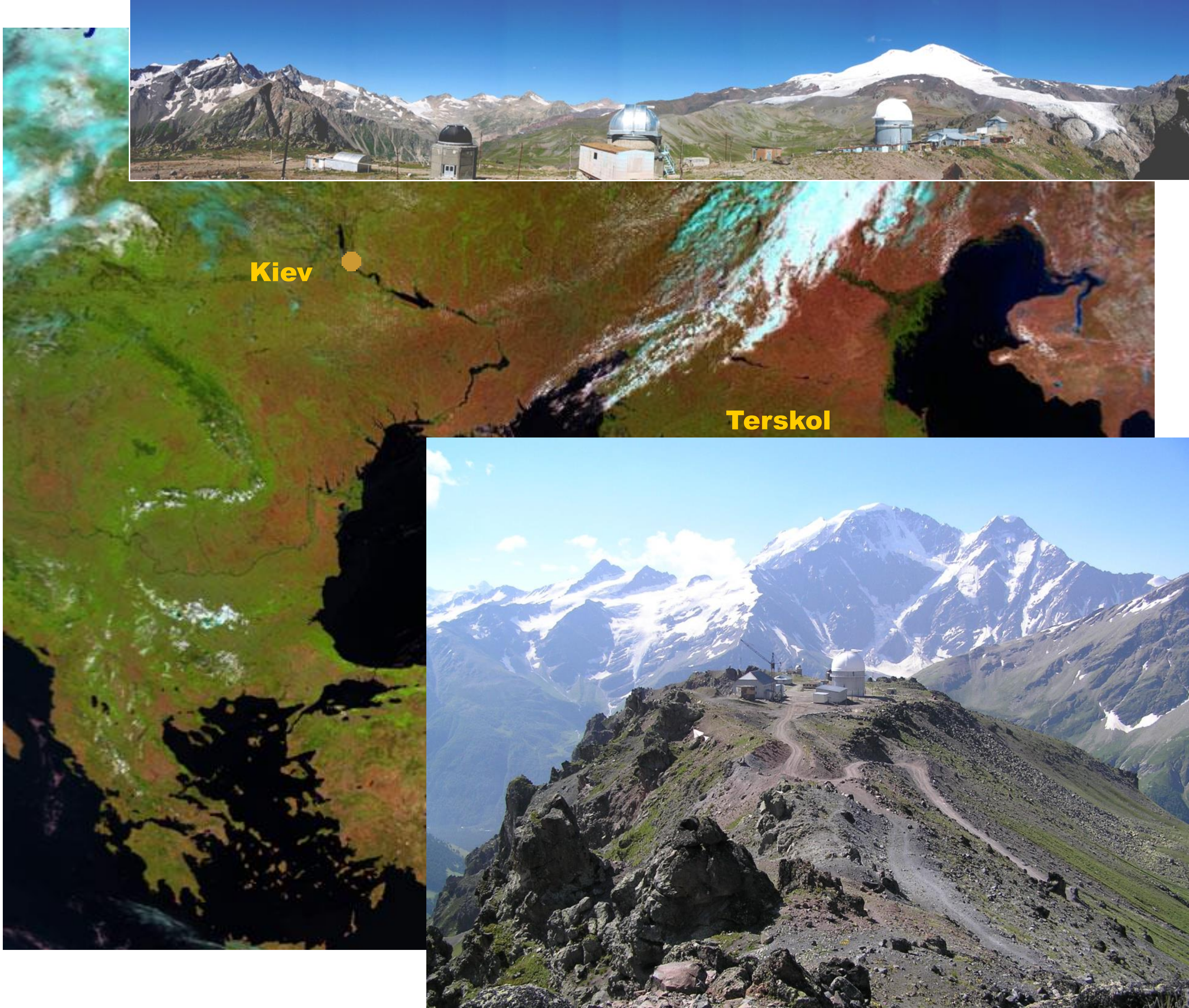
Follow-up observations of NEAs at the Terskol Observatory

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

ICAMER Observatory

National Academy of Sciences of Ukraine


Kiev
Terskol

FACILITIES & INSTRUMENTATION

- 2-m Ritchey-Chretien-Coude telescope
- Large solar telescope ACU-26
- Zeiss-600 telescope
- Small telescopes (11” and 14”)

- High-resolution Echelle spectrograph
- Multimode spectrometer
- High-speed two-channel photometer
- Several specified photometers and CCDs
- Low-resolution spectrograph

Location:

Terskol Peak in the Northern Caucasus
(43°16’29”N, 42°30’03”E, 3120 m asl)

Main mirror
d=2m, f= 5.6m

Ritchey-Chretien system

equivalent focal length: 16 m
field of view: 108’

Coude system

equivalent focal length: 72 m
field of view: 5’

High-resolution Echelle spectrograph
Multimode spectrometer
High-speed two-channel photometer
Several specified photometers and CCDs

CCD Camera FLI PL4301
Field of view: 11x11 arcmin

The photometric complex of the 2-m telescope includes a two-channel high-speed photometer with cooled photo-multipliers, UBVRI filters and a CCD guiding system. This complex has a precise timing and synchronization system based on the GPS smart antenna Acutime-2000. The accuracy of the timing and synchronization is better than l ms.

Large solar telescope ACU-26

Zeiss-600 telescope

Small telescopes

Meade LX 200 GPS 14”

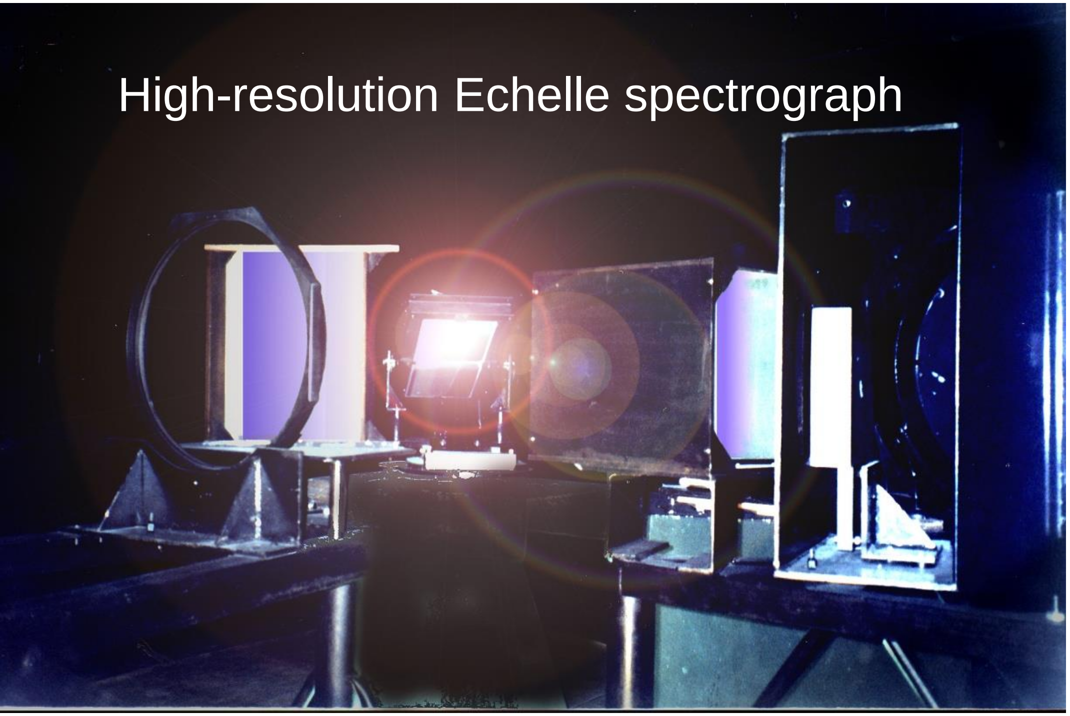
Focal length 3550 mm

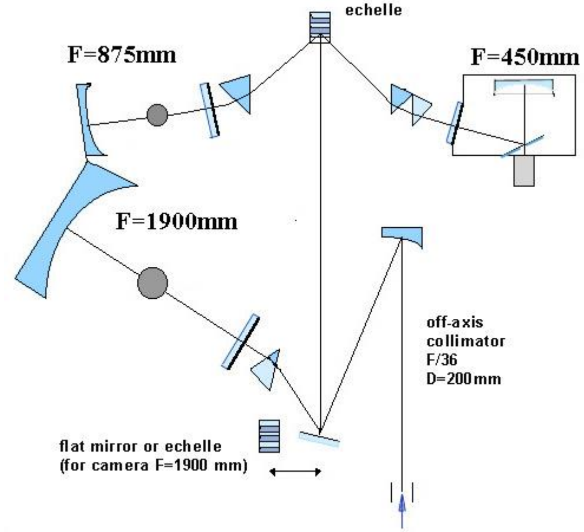
Celestron NexStar GPS 11”

F 2800 mm D/F 1:10

Main research areas

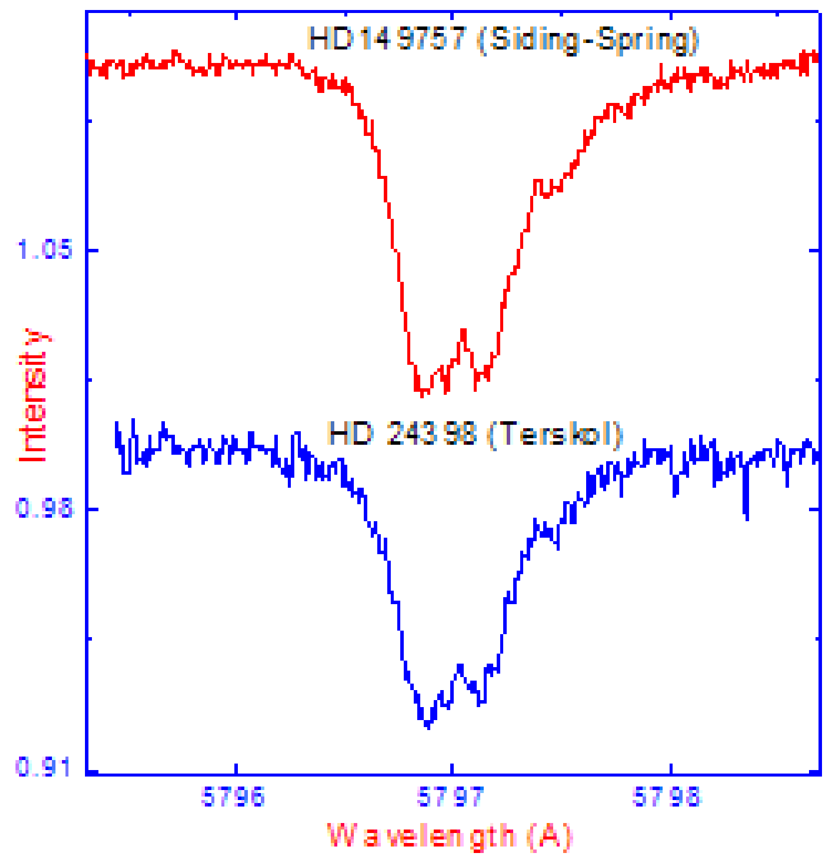
- High-resolution spectroscopy of interstellar clouds
- Astrometry and photometry of Solar System bodies
- Search for optical afterglow of gamma ray bursts
- Follow-up observations of NEOs





Study of diffuse interstellar clouds

Collaborator: Center for Astronomy of Copernik University, Poland



Astrometry and photometry of Solar System bodies

Photometric investigation of the comet C/2009 P1 (Garradd) at pre-perihelion

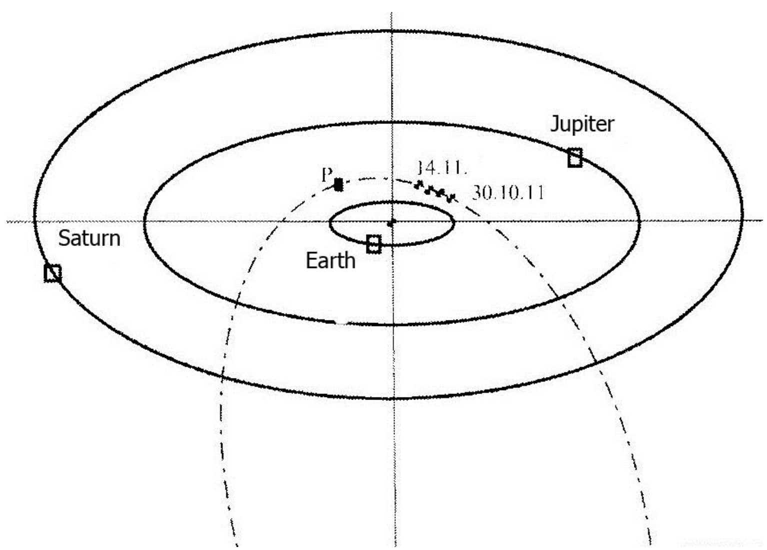
Observations were obtained with the 60-cm telescope Zeiss-600

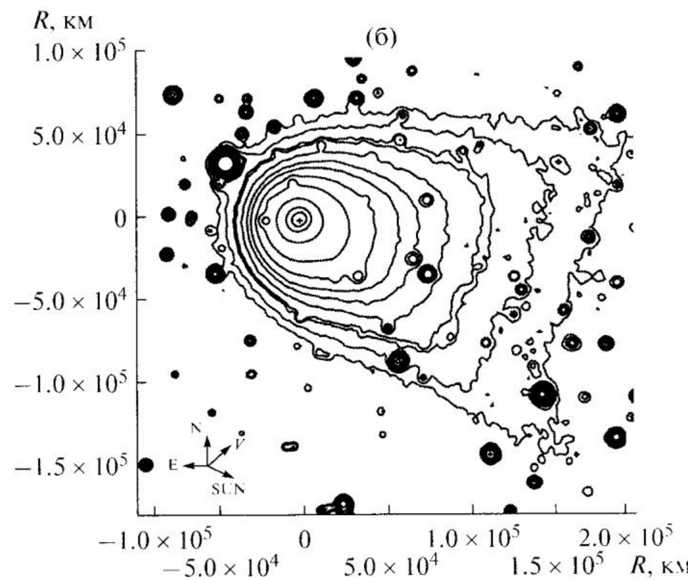
Narrow-band filters were used for selecting the BC (4450/67 Å), GC (5260/56 Å), RC (7128/58 Å), continuum, and C2 (5141/118 Å), CN (3870/62 Å), and C3 (4062/62 Å) emissions.

The production rate for dust particles and the spectral gradient of reflectivity of the dust in the blue and red continuum have been obtained from the photometric observations.

The following quantities have been estimated: the column density of molecules and their production rates.

Conclusion: the physical parameters of comet C/2009 P1 (Garradd) are close to the average characteristics of typical dynamically new comets and Oort cloud comets.





RC filter; 14/11/2011

Observations of NEAs

ZEISS-600

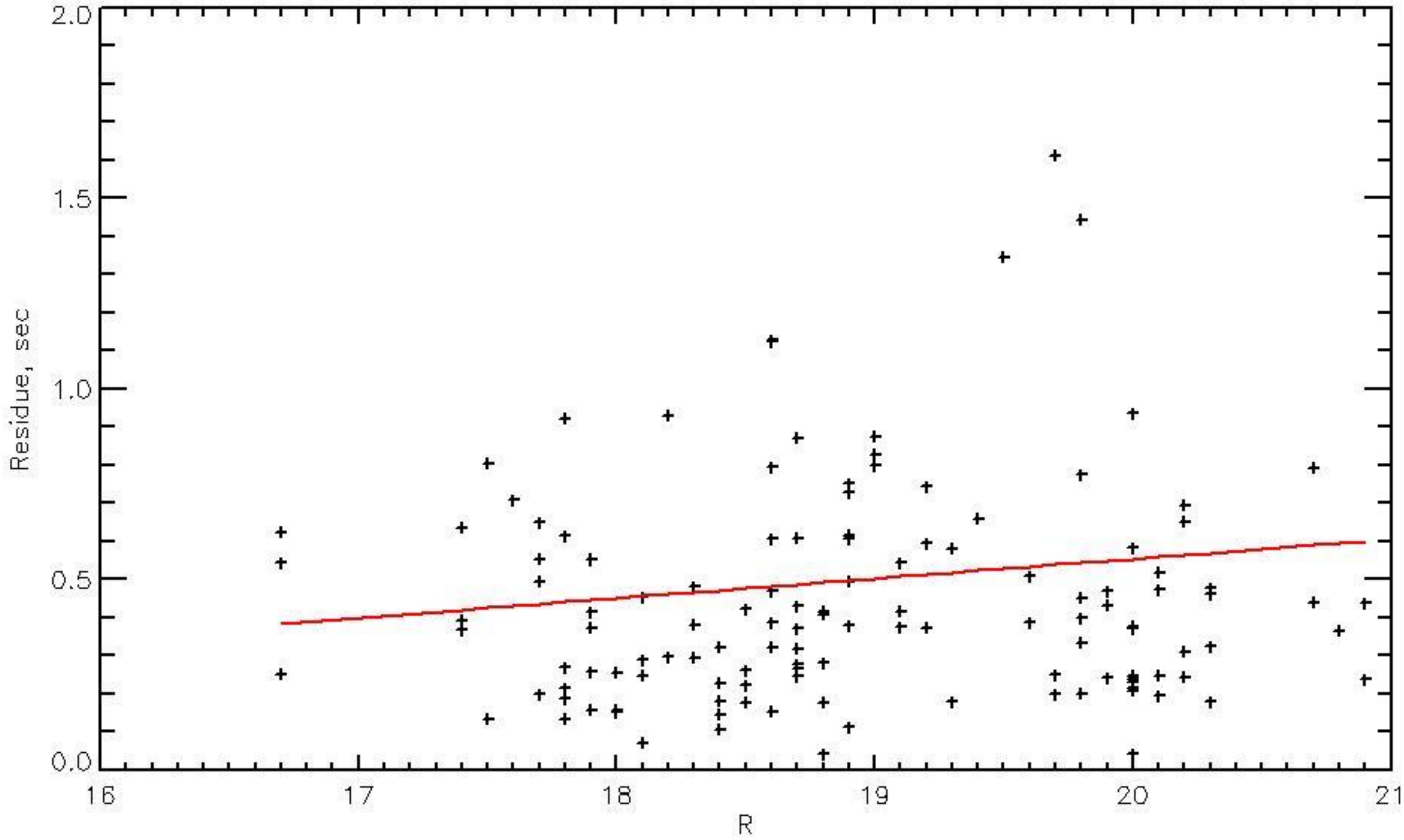
- Astrometry (down to V~21.5 mag)
- Photometry (down to V~18 mag) and
- Spectrophotometry (down to V~14.5 mag)


Zeiss-600
F/D 1/12.9
focal length 7750 mm
field of view 10.9 x 10.9 arcmin
limiting mfgnitude 21.2
SBIG STL-1001 CCD camera
(1024x1024) 24x24microns

Astrometry

- In 2003-2014, positions of more than 200 NEOs were detected.
- An accuracy in the mean is about 0.2-0.3 arcseconds.
- Precise astrometric data have been continuously reported to the Minor Planet Center.

Accuracy achieved in positions of NEAs



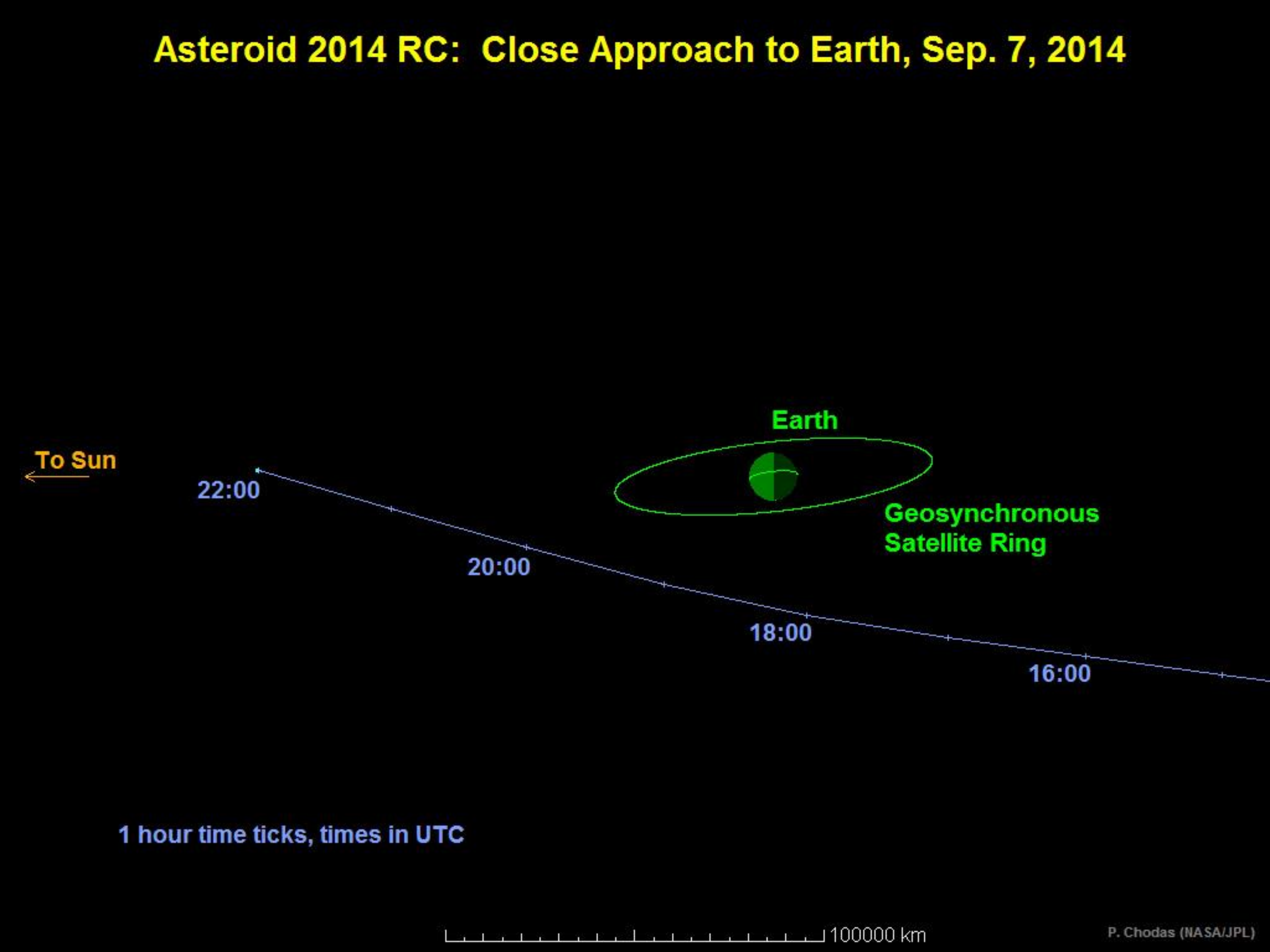
Selection criterion for observation

- PHAs with unknown physical parameters
  - follow-up observations during close approach to the Earth
  - min distance < 20 LD
  - abs magnitude < 20

- Targets of opportunity

  (recently discovered objects (MPC list), risk lists, Gaia-Fun-SSO training campaigns, etc.)

NEAs	H [mag]		D [m]
2013 RE32	24.60	AM	30 - 80
2013 RF36	16.90	AP	1.3 - 2.8 km
2013 VZ11	20.60	AM	220 - 510
2013VA12	22.70	AP	80 - 190
2013WH	21.30	AM	160 - 370
2014 DJ10	23.20	AP	60 - 150
2014 DB11	21.20	AM	170 - 380
2002 SR41	20.10	AP	280-640
2013 XM24	19.0	AP	500-1100
2001 RZ11	16.50	AM	1.5-3.4 km
2014 RC	26.8	AP	10-20
2014 TN17	21.60	AP	140-320
2014 SM143	20.30	AP	260-580
2014 SX261	22.30	AP	100-230
2011 TB4	25.40	AP	20-50
2014 TV	24.40	AP	30-80
2340 (Hathor)	20.20	AT	210


Asteroid 2014 RC: Close Approach to Earth, Sep. 7, 2014
Earth
To Sun
22:00
Geosynchronous Satellite Ring
20:00
18:00
16:00
1 hour time ticks, times in UTC
100000 km
P. Chodas (NASA/JPL)

2014 RC was discovered by the Catalina Sky Survey on Sep. 1.
2014 RC is roughly 15 meters in diameter that made an extremely close approach to Earth at 0.1 Earth-Moon distances on 2014 September 7. This was one of the closest approaches known an object of this size or larger.

www.minorplanetcenter.net/db_search/show_object?

2014 09 05.96419	22 22 34.39	-16 53 14.1	17.3 R	B18 – Terskol	MPS 530221
2014 09 05.96806	22 23 06.51	-16 53 40.6	17.1 R	I99 – Observatorio Blanquita, Vaciamadrid	MPS 530221
2014 09 05.96991	22 22 33.93	-16 53 26.3	17.4 R	B18 – Terskol	MPS 530221
2014 09 05.97529	22 23 05.56	-16 54 02.3	17.2 R	I99 – Observatorio Blanquita, Vaciamadrid	MPS 530221
2014 09 05.97564	22 22 33.50	-16 53 38.5	17.3 R	B18 – Terskol	MPS 530221
2014 09 05.975697	22 22 57.34	-16 54 42.5	17.7 V	B04 – OAVdA, Saint-Barthelemy	MPS 530221
2014 09 05.98135	22 22 33.12	-16 53 50.8	17.5 R	B18 – Terskol	MPS 530221
2014 09 05.98174	22 23 04.65	-16 54 21.6	17.0 R	I99 – Observatorio Blanquita, Vaciamadrid	MPS 530221
2014 09 05.98707	22 22 32.76	-16 54 02.7	17.5 R	B18 – Terskol	MPS 530221
2014 09 05.988310	22 22 55.86	-16 55 18.2	17.0 V	B04 – OAVdA, Saint-Barthelemy	MPS 530221
2014 09 05.99280	22 22 32.45	-16 54 14.7	17.5 R	B18 – Terskol	MPS 530221
2014 09 05.995314	22 22 55.06	-16 55 37.6	17.0 V	B04 – OAVdA, Saint-Barthelemy	MPS 530221
2014 09 05.99852	22 22 32.19	-16 54 26.6	17.2 R	B18 – Terskol	MPS 530221
2014 09 06.002317	22 22 54.27	-16 55 56.2	17.6 V	B04 – OAVdA, Saint-Barthelemy	MPS 530221
2014 09 06.00424	22 22 31.96	-16 54 38.6	17.3 R	B18 – Terskol	MPS 530221

http://newton.dm.unipi.it/neodys/index.php?pc=2.1.2&o=B18&ab

Y28	O	C		2014-02-03.91466	1.000E-05	10:25:24.490	1.500E-01	0.660	F	0.000	-0.150	+50° 46' 33.20"	1.000E-01	0.590	F	0.000	0.303	16.3 R	0.70	0.11	q	B18	0.57	Yes	Yes
Y28	O	C		2014-02-03.96802	1.000E-05	10:24:56.800	1.500E-01	0.660	F	0.000	-0.018	+51° 13' 22.40"	1.000E-01	0.590	F	0.000	0.129	16.7 R	0.70	0.52	q	B18	0.22	Yes	Yes
J10	O	C	K	2014-02-23.87250	1.000E-05	11:00:05.360	1.500E-01	0.660	F	0.000	0.162	+11° 24' 03.10"	1.000E-01	0.590	F	0.000	-0.441	19.7 R	0.70	0.26	q	B18	0.80	Yes	Yes
J10	O	C	K	2014-02-23.87689	1.000E-05	11:00:05.070	1.500E-01	0.660	F	0.000	0.249	+11° 24' 41.20"	1.000E-01	0.590	F	0.000	-0.602	19.6 R	0.70	0.16	q	B18	1.10	Yes	Yes
B11	O	C		2014-02-23.88135	1.000E-05	11:51:17.000	1.500E-01	0.660	F	0.000	0.216	+11° 38' 20.60"	1.000E-01	0.590	F	0.000	0.091	19.3 R	0.70	0.31	q	B18	0.36	Yes	Yes
B11	O	C		2014-02-23.88575	1.000E-05	11:51:17.250	1.500E-01	0.660	F	0.000	0.132	+11° 38' 04.60"	1.000E-01	0.590	F	0.000	0.295	19.5 R	0.70	0.51	q	B18	0.54	Yes	Yes
B11	O	C		2014-02-23.89014	1.000E-05	11:51:17.490	1.500E-01	0.660	F	0.000	-0.082	+11° 37' 48.00"	1.000E-01	0.590	F	0.000	-0.130	19.4 R	0.70	0.41	q	B18	0.25	Yes	Yes
C	O	C		2014-09-05.96419	1.000E-05	22:22:34.390	1.500E-01	0.660	F	0.000	-0.064	-16° 53' 14.10"	1.000E-01	0.590	F	0.000	-0.222	17.3 R	0.70	0.04	q	B18	0.39	Yes	Yes
C	O	C		2014-09-05.96991	1.000E-05	22:22:33.930	1.500E-01	0.660	F	0.000	-0.078	-16° 53' 26.30"	1.000E-01	0.590	F	0.000	-0.054	17.4 R	0.70	0.14	q	B18	0.15	Yes	Yes
C	O	C		2014-09-05.97564	1.000E-05	22:22:33.500	1.500E-01	0.660	F	0.000	-0.139	-16° 53' 38.50"	1.000E-01	0.590	F	0.000	0.036	17.3 R	0.70	0.05	q	B18	0.22	Yes	Yes
C	O	C		2014-09-05.98135	1.000E-05	22:22:33.120	1.500E-01	0.660	F	0.000	-0.016	-16° 53' 50.80"	1.000E-01	0.590	F	0.000	-0.113	17.5 R	0.70	0.26	q	B18	0.19	Yes	Yes
C	O	C		2014-09-05.98707	1.000E-05	22:22:32.760	1.500E-01	0.660	F	0.000	-0.136	-16° 54' 02.70"	1.000E-01	0.590	F	0.000	0.070	17.5 R	0.70	0.26	q	B18	0.24	Yes	Yes
C	O	C		2014-09-05.99280	1.000E-05	22:22:32.450	1.500E-01	0.660	F	0.000	-0.096	-16° 54' 14.70"	1.000E-01	0.590	F	0.000	0.089	17.5 R	0.70	0.27	q	B18	0.21	Yes	Yes
C	O	C		2014-09-05.99852	1.000E-05	22:22:32.190	1.500E-01	0.660	F	0.000	0.063	-16° 54' 26.60"	1.000E-01	0.590	F	0.000	0.107	17.2 R	0.70	-0.02	q	B18	0.20	Yes	Yes
C	O	C		2014-09-06.00424	1.000E-05	22:22:31.960	1.500E-01	0.660	F	0.000	0.038	-16° 54' 38.60"	1.000E-01	0.590	F	0.000	-0.049	17.3 R	0.70	0.08	q	B18	0.10	Yes	Yes
N17	O	C		2014-10-03.03698	1.000E-05	00:52:31.880	1.500E-01	1.500	F	0.000	0.023	+22° 31' 59.10"	1.000E-01	1.500	F	0.000	0.209	19.0 R	0.70	-0.14	v	B18	0.14	Yes	Yes
N17	O	C		2014-10-03.03918	1.000E-05	00:52:31.390	1.500E-01	1.500	F	0.000	0.043	+22° 32' 11.10"	1.000E-01	1.500	F	0.000	0.765	19.3 R	0.70	0.16	v	B18	0.51	Yes	Yes
N17	O	C		2014-10-03.04137	1.000E-05	00:52:30.910	1.500E-01	1.500	F	0.000	0.168	+22° 32' 22.00"	1.000E-01	1.500	F	0.000	0.272	19.1 R	0.70	-0.04	v	B18	0.21	Yes	Yes
M143	O	C		2014-10-06.05016	1.000E-05	04:05:35.410	1.500E-01	1.500	F	0.000	-0.126	-22° 19' 15.10"	1.000E-01	1.500	F	0.000	-0.157	17.9 R	0.70	-0.09	v	B18	0.13	Yes	Yes
M143	O	C		2014-10-06.05236	1.000E-05	04:05:35.810	1.500E-01	1.500	F	0.000	-0.050	-22° 19' 13.10"	1.000E-01	1.500	F	0.000	0.177	18.1 R	0.70	0.11	v	B18	0.12	Yes	Yes
M143	O	C		2014-10-06.05382	1.000E-05	04:05:36.050	1.500E-01	1.500	F	0.000	-0.355	-22° 19' 12.40"	1.000E-01	1.500	F	0.000	-0.231	18.0 R	0.70	0.01	v	B18	0.28	Yes	Yes

Astrometry

NEODyS-2

Near Earth Objects - Dynamic Site

Sponsored by esa | Università di Pisa | SpaceDyS

Go to NEA »

Home | Objects | Observatories | Search | Risk page | NEA elements | Related sites | Info & Credits

B18 » OBSERVATIONS AND RESIDUALS [Help]

Parallax info

Obs & residuals

B18-Terskol

Detections | Residuals | Detections & Residuals

[1-200] [201-400] [401-600] [601-800] [801-861]

Designation	T	Tech	N	Date		Right Ascension						Declination						Apparent Magnitude			Star Catalog	Site code	χ	Used A	Used M
				yr-mo-day	precision	hr:min:sec	precision	rms	F	bias	residual	deg min sec	precision	rms	F	bias	residual	mag/col	rms	residual					
2005YU55	O	C		2011-11-19.88219	1.000E-05	02:33:15.860	1.500E-01	0.660	F	0.000	-0.068	+16° 33' 17.90"	1.000E-01	0.590	F	0.000	-0.633	16.5 R	0.70	-0.40	u	B18	1.08	Yes	Yes
2011WK5	O	C	K	2011-11-21.73404	1.000E-05	02:02:08.040	1.500E-01	0.660	F	0.000	0.526	+30° 01' 02.90"	1.000E-01	0.590	F	0.000	-0.584	19.5 R	0.70	-0.03	u	B18	1.28	Yes	Yes
2011WK5	O	C	K	2011-11-21.73823	1.000E-05	02:02:09.240	1.500E-01	0.660	F	0.000	-0.050	+30° 00' 59.80"	1.000E-01	0.590	F	0.000	0.032	19.5 R	0.70	-0.03	u	B18	0.10	Yes	Yes
2011WK5	O	C	K	2011-11-21.74033	1.000E-05	02:02:09.910	1.500E-01	0.660	F	0.000	0.556	+30° 00' 58.00"	1.000E-01	0.590	F	0.000	0.103	19.4 R	0.70	-0.13	u	B18	0.87	Yes	Yes
2011YA	O	C		2011-12-16.99751	1.000E-05	07:46:07.250	1.500E-01	1.500	F	0.000	0.222	+37° 58' 50.50"	1.000E-01	1.500	F	0.000	-0.202	17.4 R	0.70	-0.62	v	B18	0.20	Yes	Yes
2011YA	O	C		2011-12-17.00101	1.000E-05	07:46:07.290	1.500E-01	1.500	F	0.000	0.170	+37° 58' 55.60"	1.000E-01	1.500	F	0.000	-0.279	17.6 R	0.70	-0.42	v	B18	0.22	Yes	Yes
2011YA	O	C		2011-12-17.00522	1.000E-05	07:46:07.330	1.500E-01	1.500	F	0.000	0.009	+37° 59' 02.00"	1.000E-01	1.500	F	0.000	-0.103	17.7 R	0.70	-0.32	v	B18	0.07	Yes	Yes
2011YA	O	C		2011-12-17.00733	1.000E-05	07:46:07.350	1.500E-01	1.500	F	0.000	-0.073	+37° 59' 04.90"	1.000E-01	1.500	F	0.000	-0.320	17.5 R	0.70	-0.52	v	B18	0.22	Yes	Yes
2011XA3	O	C		2011-12-17.01147	1.000E-05	08:08:37.720	1.500E-01	1.500	F	0.000	0.166	+49° 42' 30.60"	1.000E-01	1.500	F	0.000	0.096	17.3 R	0.70	0.10	v	B18	0.12	Yes	Yes
2011XA3	O	C		2011-12-17.01358	1.000E-05	08:08:37.400	1.500E-01	1.500	F	0.000	0.265	+49° 42' 52.10"	1.000E-01	1.500	F	0.000	-0.336	17.3 R	0.70	0.10	v	B18	0.29	Yes	Yes
2011XA3	O	C		2011-12-17.01777	1.000E-05	08:08:36.720	1.500E-01	1.500	F	0.000	0.034	+49° 43' 36.00"	1.000E-01	1.500	F	0.000	-0.011	16.8 R	0.70	-0.40	v	B18	0.02	Yes	Yes
2011XA3	O	C		2011-12-17.02128	1.000E-05	08:08:36.190	1.500E-01	1.500	F	0.000	0.229	+49° 44' 13.00"	1.000E-01	1.500	F	0.000	0.464	16.8 R	0.70	-0.39	v	B18	0.34	Yes	Yes
2011YQ1	O	C		2011-12-18.82374	1.000E-05	07:04:56.780	1.500E-01	0.660	F	0.000	0.067	+22° 30' 27.60"	1.000E-01	0.590	F	0.000	-0.072	18.4 R	0.70	-0.05	u	B18	0.16	Yes	Yes
2011YQ1	O	C		2011-12-18.82723	1.000E-05	07:04:56.700	1.500E-01	0.660	F	0.000	-0.222	+22° 30' 14.10"	1.000E-01	0.590	F	0.000	0.205	18.6 R	0.70	0.15	u	B18	0.50	Yes	Yes
2011YQ1	O	C		2011-12-18.83073	1.000E-05	07:04:56.660	1.500E-01	0.660	F	0.000	0.114	+22° 30' 00.10"	1.000E-01	0.590	F	0.000	0.032	18.4 R	0.70	-0.05	u	B18	0.18	Yes	Yes

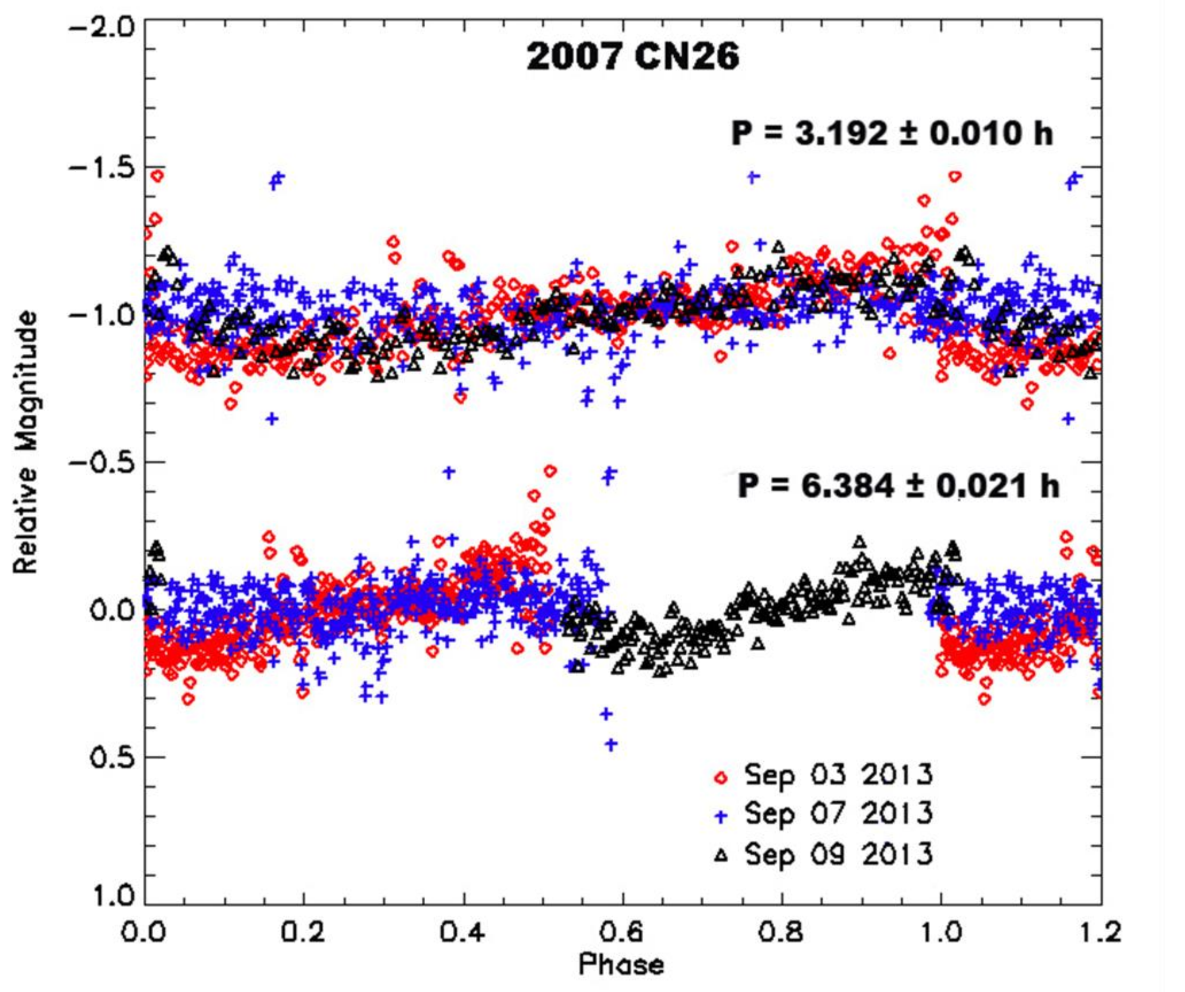
Photometry

Zeiss-600

- Photometric observations of asteroids 2005 AY28, 2007 CN26 and 2013 ET were conducted with individual exposure times of 10-30 s. In order to enhance the signal-to-noise ratio, all CCD images were taken in “white light”.
- To determine rotation parameters of the observed PHAs, we used techniques based on Fourier analysis, Lomb normalized periodogram, phase dispersion minimization (PDM), and Hotelling's T-squared statistic, respectively. Comparison of the results showed that the PDM technique and a modified version of the Hotelling test are most appropriate for the task.

2007 CN26

Photometric CCD data of this Apollo asteroid (D = 180-400 m) were obtained on three nights in early September 2013 - after its close approach (0.0305 AU) on August 28, 2013. Due to the ambiguous light curves of this PHA, estimation of its rotation period was rather complicated. From the light curve analysis by Hotelling's T**2** statistic, a rotation period of 3.192 ± 0.010 h was derived, with an amplitude of 0.3m. Folding the data to the doubled period P = 6.384 ± 0.021 h (assuming a two maxima-minima model) gives a more pronounced periodicity



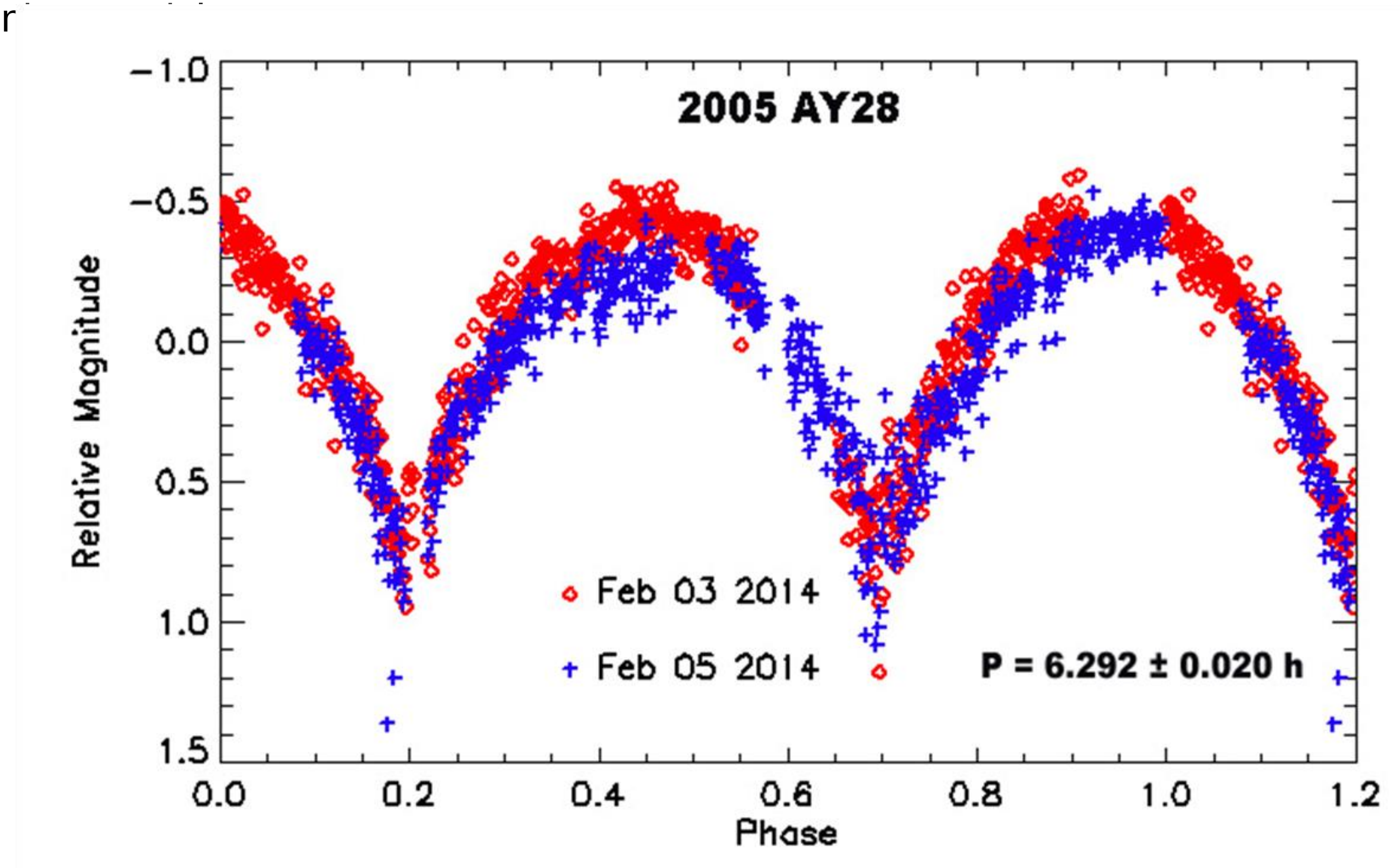
Composite light curves of 2007 CN26.

Two possible rotation period solutions are plotted (each is shifted along the Y-axis).

2005 AY28

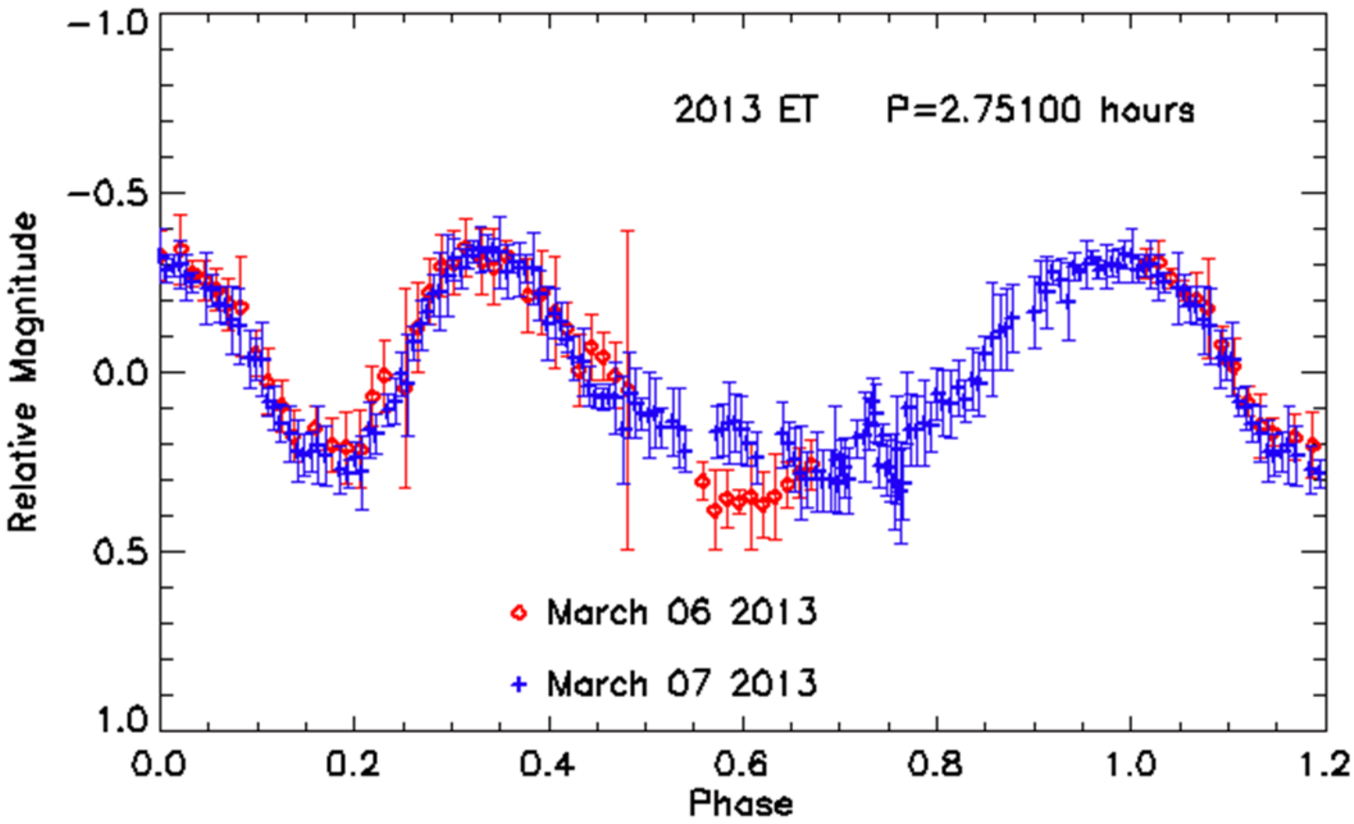
This Aten-type asteroid (D =150-330 m) made an Earth close-approach of 0.039 AU on February 7, 2014. It seems very likely that 2005 AY28 has an elongated shape: its light curves obtained at Terskol on February 3 and 5, 2014, showed that the total amplitude exceeds 1.5m. We found a best-fit period of 6.292 ± 0.020 h using the PDM technique. It is essential to note that we discarded here anshorter period on the assumption of a two

maxima-mir



Earth on March 9, 2013. Photometric observations of this PHA were performed at the Terskol Observatory shortly after its discovery, on March 6 and 7, 2013, when its V magnitude was about 15.8^m and 15.2^m, respectively.

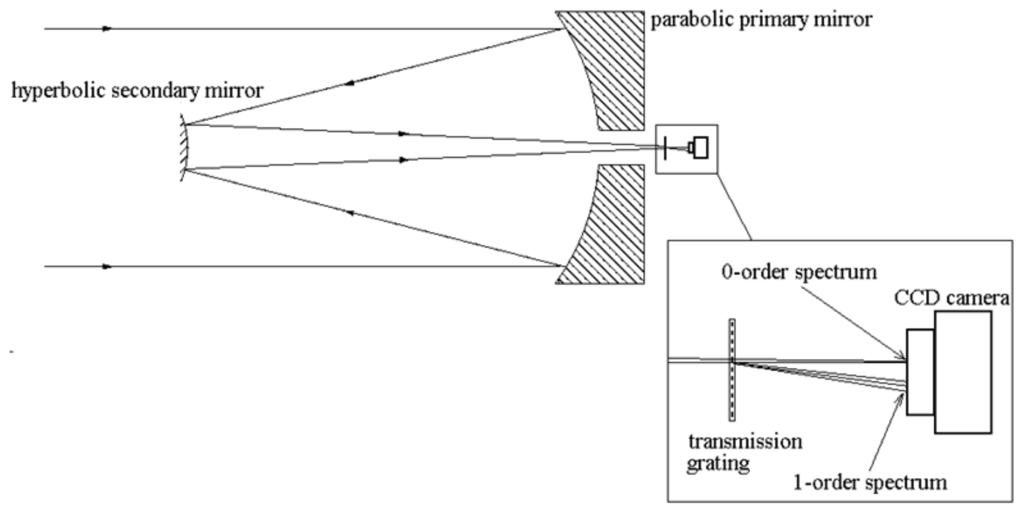
We obtained full phase coverage and found a rotation period of 2.751 ± 0.002 h, amplitude of about 0.8m, and the *a/b* axis ratio of about 2.1. Light curve analysis was done using both the PDM technique and Hotelling's T2 statistic; as results have shown the PDM technique provides the most acceptable solution for rotation period in this case.



Low-resolution spectroscopy

Spectra of asteroids have been obtained by using a low-resolution imaging spectrograph attached to the Zeiss-600 telescope

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.

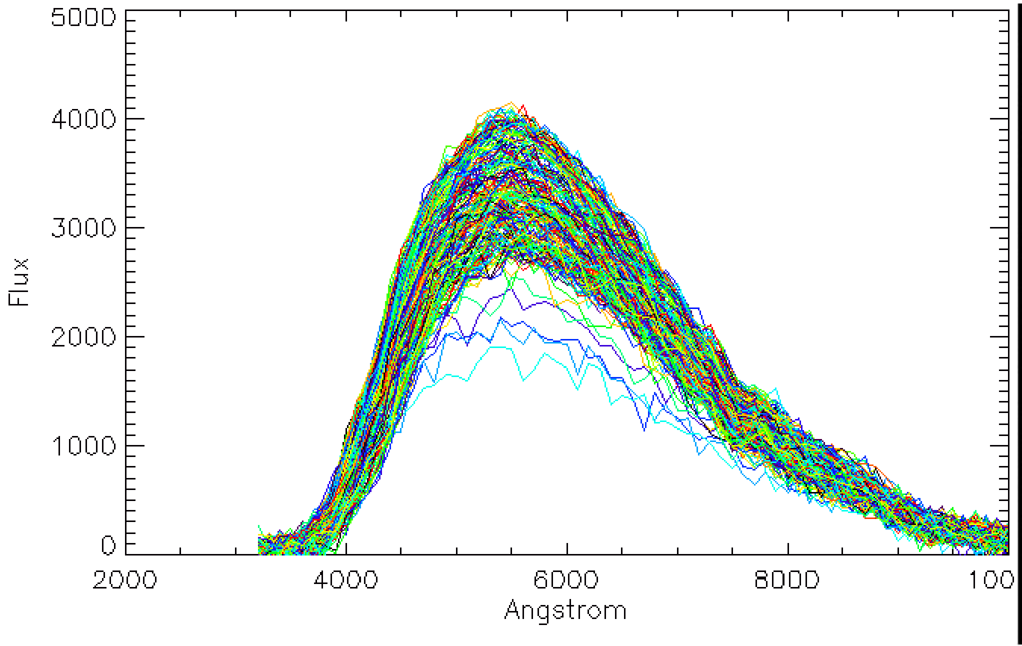


. Optical layout of a slitless spectrograph mounted on the Cassegrain reflector.

A **slitless spectrograph for observing transient events with small telescopes**
Zhilyaev B.E., Sergeev O.V., Andreev M.V., Godunova V.G., Reshetnyk V.M., Tarady V.K.
// Ground-based & Airborne Instrumentation for Astronomy IV at the SPIE Astronomical Telescopes + Instrumentation 2012 Meeting (Amsterdam, 1-6 July 2012). – eds. I.S.McLean, S.R.Ramsay, H.Takami - Proc. of SPIE Vol. 8446, 84468I (11 p.) doi: 10.1117/12.925730

TAXONOMIC CLASSIFICATION TECHNIQUE

- *The taxonomy introduced by Tedesco et al. uses the minimum number of observable parameters necessary to account for the physical processes being classified, i.e. the strengths of the two principal absorption features found in asteroid visual-wavelength-range spectra and the albedo.*
- *Three parameters (U-V and u – x color indices and visual geometric albedo) were calculated and used to determine taxonomic classes of PHAs.*
- *U-V and u – x colors were obtained through mathematical convolution of the spectra with the filter transmission curves.*



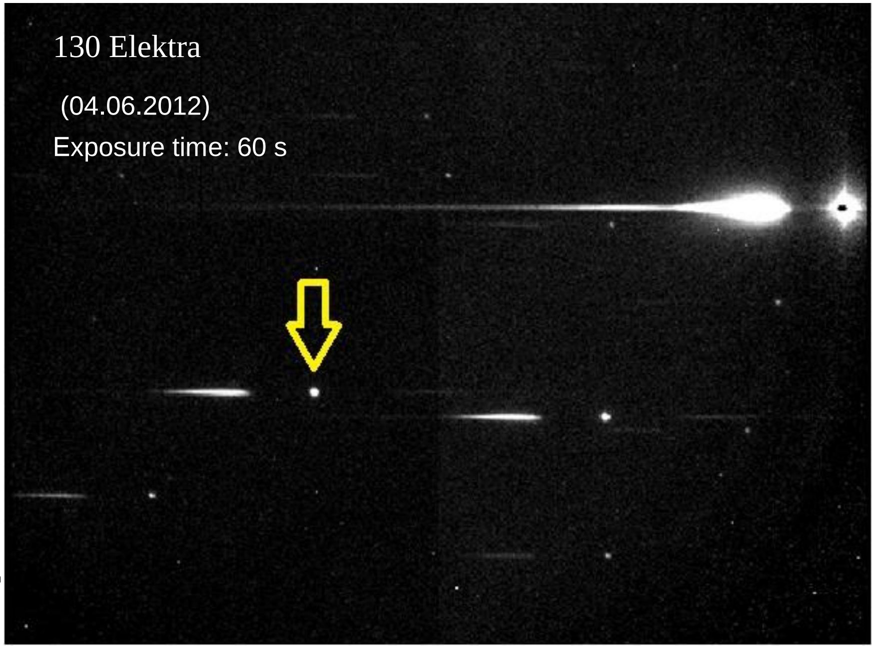
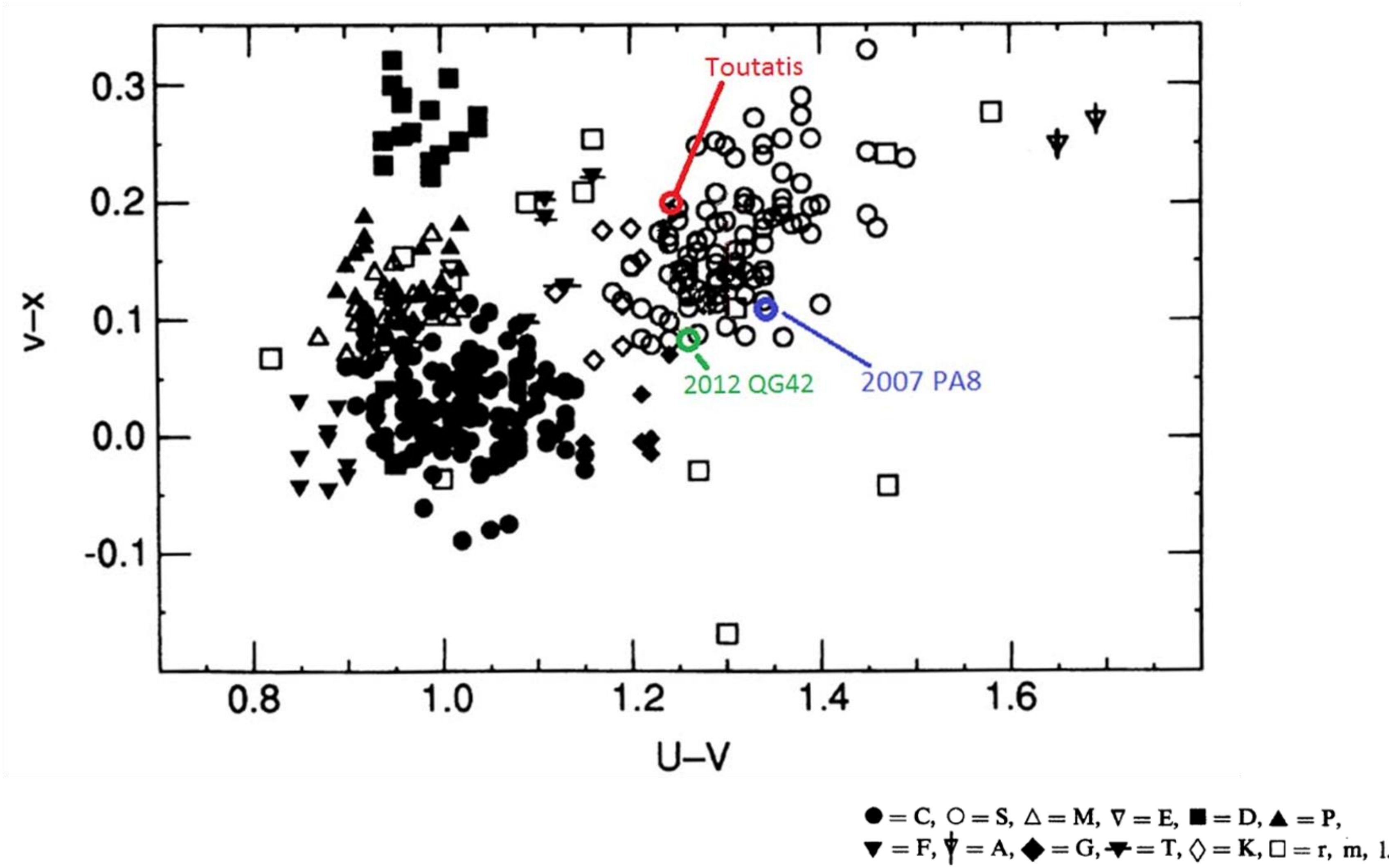
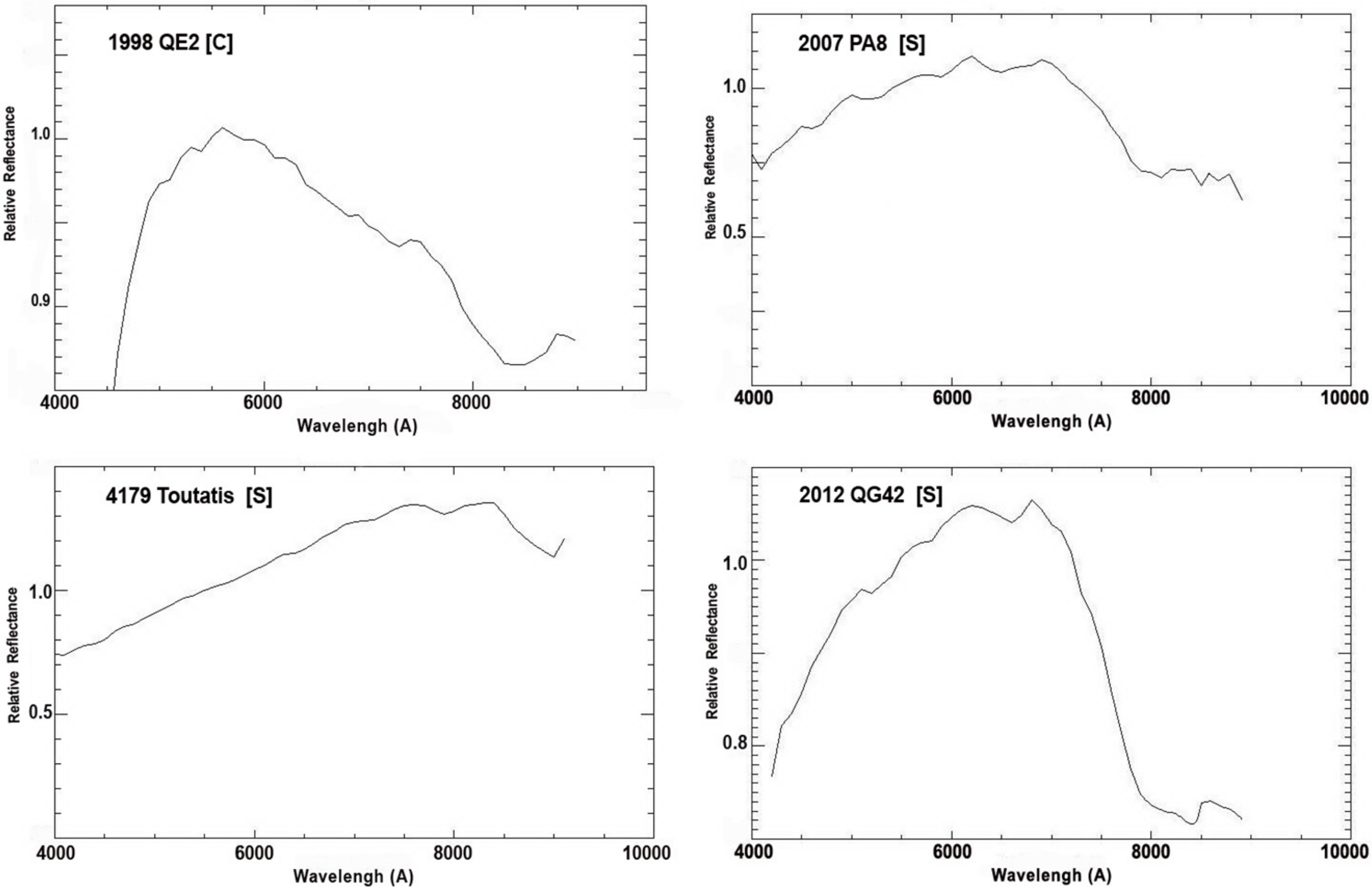


Figure (taken from [Tedesko et all]) shows the U-V vs u – x color-color plot for the full sample of data used by Tedesko et all (357 asteroids). Colored circles indicate the three PHA, which were observed at Terskol and identified with the S taxonomic class.



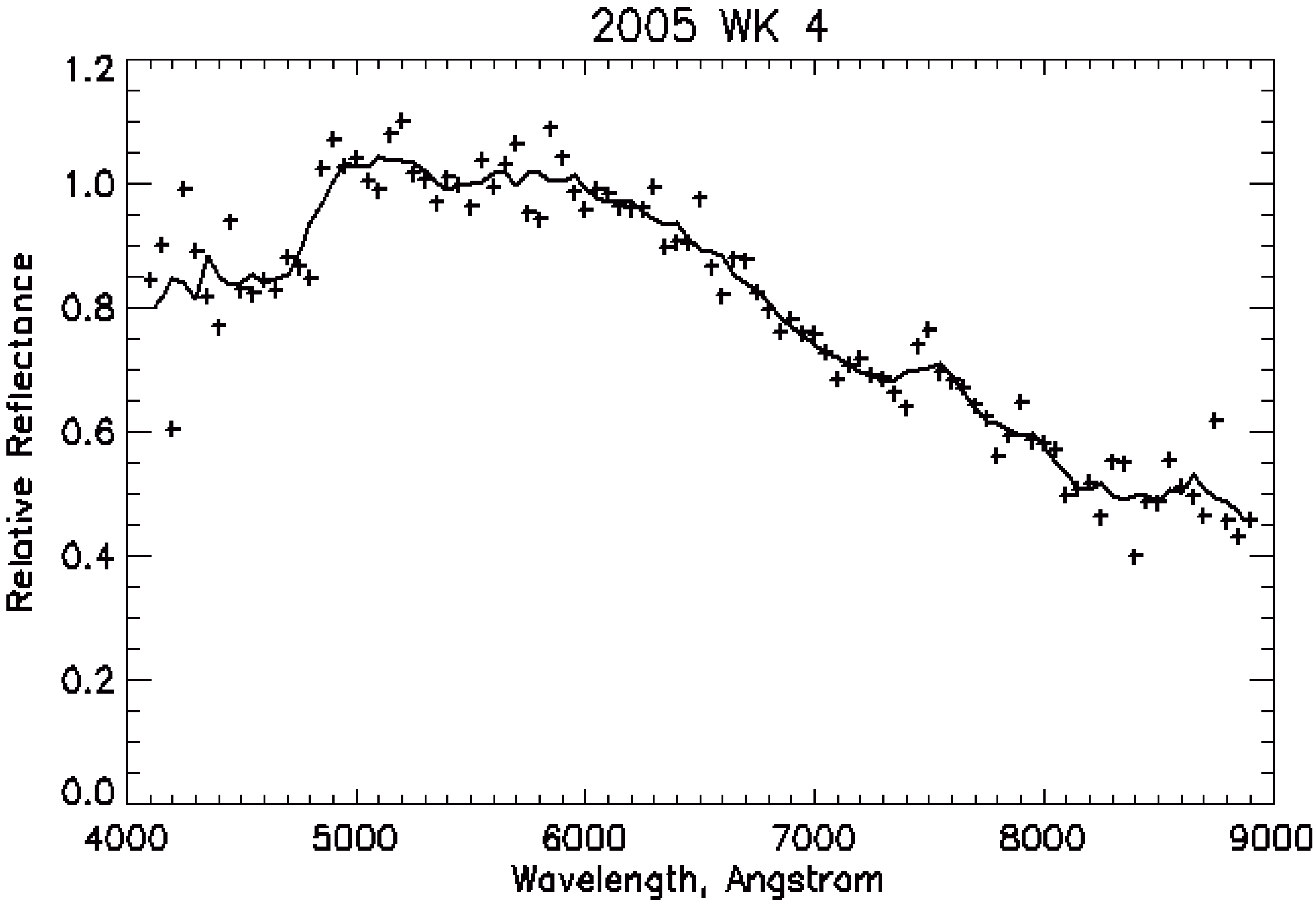


Relative reflectance spectra of asteroids 1998 QE2, 2007 PA8, 4179 Toutatis, and 2012 QG42.

2005 WK4

We have carried out low-resolution spectral observations of this PHA on August 10-12, 2013. This asteroid (280-640 m in diameter) came within 0.021 AU (8 lunar distances) to the Earth on August 9, 2013.

Figure shows the preliminary results obtained from a series of CCD images, which were taken on 11 August 2013. The relative reflectance spectrum calculated allows us to place this asteroid in the C-class.



CONCLUSIONS

- The telescope Zeiss-600 at the Terskol Observatory has been successfully used for astrometry, photometry and spectroscopy of Earth-approaching asteroids and comets.
- In 2003-2014, positions of more than 200 NEOs were detected.
- An accuracy in the mean is about 0.2-0.3 arcseconds.
- 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.
- The revealed light curves allowed us to calculate lightcurve amplitude and rotation period of asteroids.


Dmitriy Chistoprudov | Nikolay Rykov