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DISCOVERY, OBSERVATIONAL DATA AND THE ORBIT OF THE CENTAUR ASTEROID 2012 DS85

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Abstract. A project for astrometric and photometric observations of asteroids at Mt. Graham Observatory with the VATT telescope is described. One of the most important results is a discovery of the Centaur 2012 DS85. Astrometric and photometric data on the asteroid are presented. The orbit of the asteroid was computed from 67 observations. Combined with its apparent brightness, the orbit gives an absolute magnitude of 9.43. Using a typical albedo value of 0.08 for Centaurs and TNOs (Moullet et al. 2011), we get a diameter of 2012 DS85 at about 61 km.

Key words: asteroids: astrometry, photometry, orbits – asteroids: Centaurs: individual (2012 DS85)

1. INTRODUCTION

One of the research projects of the Vatican Observatory is a study of asteroids for a better prediction of their orbits. The observing program on the 1.8 m telescope VATT is targeted on observing the Main Belt and the Centaur group asteroids, trans-neptunian objects (TNO), as well as on the search of new objects. First astrometric observations of asteroids and comets with the VATT at the Mt. Graham Observatory (IAU code 290, longitude 109.89201 W, latitude 32.70133 N, altitude 3178 m) were initiated in 2000–2001 using CCD images exposed in the primary focus of the VATT (Hergenrother & Spahr 2001). The first new asteroid, (220696) = 2000 YJ143, was discovered in 2000 by W. H. Ryan. In the period of 2000–2005 Ryan with his assistants have discovered about 60 new objects. In 2007, 75 new asteroids were discovered by C. W. Hergenrother.

A new observational program for the search and observations of asteroids was started in 2009 by R. P. Boyle and K. Černis. The first object observed was an asteroid of the Centaur group, 2009 HW77, discovered by Černis & Eglitis (2009) in April of 2009. This interesting asteroid was observed with the VATT in three oppositions (2010–2012), and its new orbit was calculated by Wlodarczyk et al. (2011). Since 2010 the fields are imaged in the Gregorian focus (f/9.2) with a 4K background-illuminated CCD camera and liquid nitrogen cooling. With a

Table 1. Discovery time and position of the asteroid 2012 DS85.

2012 UT	RA(J2000)	DEC(J2000)	R mag
Feb. 19.313	$08^{\mathrm{h}}\,41^{\mathrm{m}}\,49.69^{\mathrm{s}}$	$+18^\circ\,20'\,37.6''$	21.9

62×62 mm chip (2000×2000 binned pixels) the camera produces a field-of-view of $13' \times 13'$, with a scale of $0.38''$/pixel. All astrometric measurements are done using the Astrometrica software (Raab 2003). The catalogs USNO-A2.0, USNO-B1.0 and UCAC-2 serve for the selection of reference stars.

The limiting magnitude for stars on the VATT is about $R = 22.5$ on unfiltered CCD images with the exposure time 360 s and a $\sim 1''$ seeing. It is a very comfortable instrument for follow-up astrometry of poorly observed TNOs, unusual faint objects and comets. The targets for observations are selected using the public WEB tools for observers (IAU MPEC or "The NEO Confirmation Page"). About 1500 CCD images have been obtained for astrometry of asteroids and comets during the last three years. The methods of processing of CCD images and the search of asteroids on VATT exposures are more or less the same as used in our earlier papers (Černis et al. 2008, 2010, 2012b).

In 2010–2012, during the sky survey in the ecliptic regions and the follow-up astrometry of asteroids, 49 new asteroids were discovered. Among them, two are multiple-apparition objects, 10 are one-opposition objects, 37 are one opposition objects with low accuracy orbits. For six objects high precision orbits have been determined. Among the discovered asteroids, apart of 2012 DS85, there is one TNO 2012 BX85 (Černis & Boyle 2012). During investigation of our CCD frames, 380 unknown asteroids of magnitudes 21–22 were discovered, but they were not confirmed due to their faintness. Among more than thousand observations, about 210 belong to Centaurs and TNO.

2. DISCOVERY OF 2012 DS85

The asteroid 2012 DS85 was discovered in the evening of 2012 February 19 (Černis, Boyle & Laugalys 2012a). The discovery time and position are given in Table 1.

During the inspection of CCD frames the asteroid was detected in five 360 s exposures as a slow-moving object in Cancer (the motion to west at about $0.11''$/min to the elongation 158°), located only about $4'$ above the ecliptic plane, about 0.5° west of δ Cnc. This object with $R = 21.9$ mag was identified on February 21 at about 10 h UT, i.e. ~ 2 days after it was imaged. One of the authors (K.Č) has made five astrometric measurements of the new object and calculated its approximate positions for the next nights. Due to a bad seeing, the object was not found in CCD images taken on February 20. In February 21 images the object was detected at about $5'$ from the discovery place. The discovery image is shown in Figure 1. Two night positions with the 48 hour interval were reported to the MPC. After that, the object was found in the images obtained on February 22, 24, 26 and 27 evenings. On March 11 T. Spahr at MPC designated the new object as 2012 DS85 and calculated its first preliminary orbit with a period of 99 years.

3. ASTROMETRIC OBSERVATIONS AND THE ORBIT

On the VATT, during six nights of February the first 30 astrometric positions of the asteroid were collected. In April additional 37 astrometric observations were

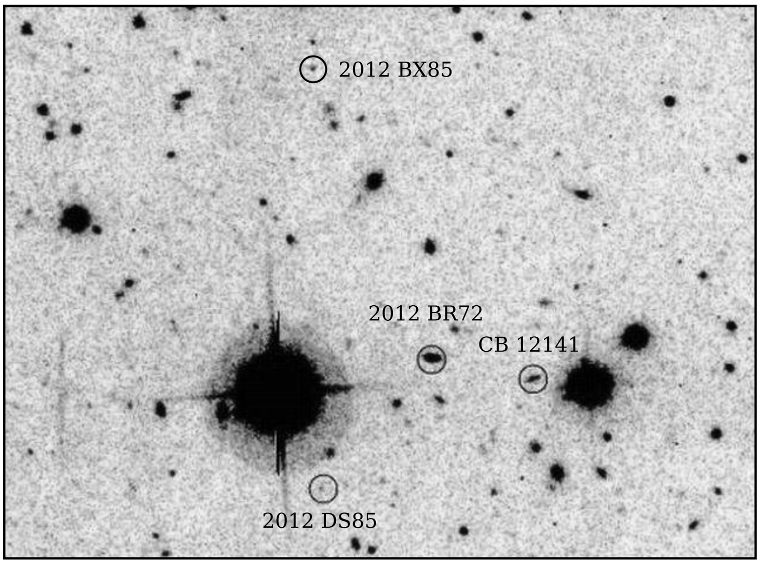

Fig. 1. Discovery image of 2012 DS85. The size of the field is $2.3' \times 2.7'$, the exposure time 6 min. Exposed with the VATT on Mt. Graham in the evening of 2012 February 19. Two Main Belt asteroids (2012 BR72 and CB 12141) and the TNO 2012 BX85 (discovered by our team on January 5) are also identified.

Table 2. Nominal orbit of 2012 DS85 from the MPO 231180.

Epoch 2012 Mar. 14.0 TT = JDT 2456000.5 MPC					
a	e	i	Ω	ω	M
AU		deg	deg	deg	deg
18.8973194	0.1172529	16.74836	128.97124	310.21461	40.61123

obtained during eight nights. The accuracy of the astrometric observation is about $\pm 0.13''$ with a signal-to-noise ratio of ~ 5 and the exposures of 6 min. Altogether, 67 astrometric positions were assembled from February 19 to April 25, all of them on the VATT. The results are listed in Table 6 at the end of this paper.

3.1. The orbit of 2012 DS85

Table 2 lists the first computed orbit of the asteroid 2012 DS85 published by the MPC in MPO 231180.[1]

Figure 2 plots the orbit of the asteroid 2012 DS85 and the three planets: Jupiter, Saturn and Uranus. Positions of planets for the epoch of discovery are marked by diamonds and of 2012 DS85 by a large star. It is evident that the orbit of the asteroid 2012 DS85 crosses the orbit of Uranus.

The MPC presents orbit of 2012 DS85 computed using all 67 observations.[2] This website also lists all the positions available.

For observations of the asteroid during the next observational window we need

[1] http:www.minorplanetcenter.net/iau/ECS/MPCArchive/2012/MPO_20120604.pdf

[2] http://www.minorplanetcenter.net/db_search/show_object?object_id=2012+DS85

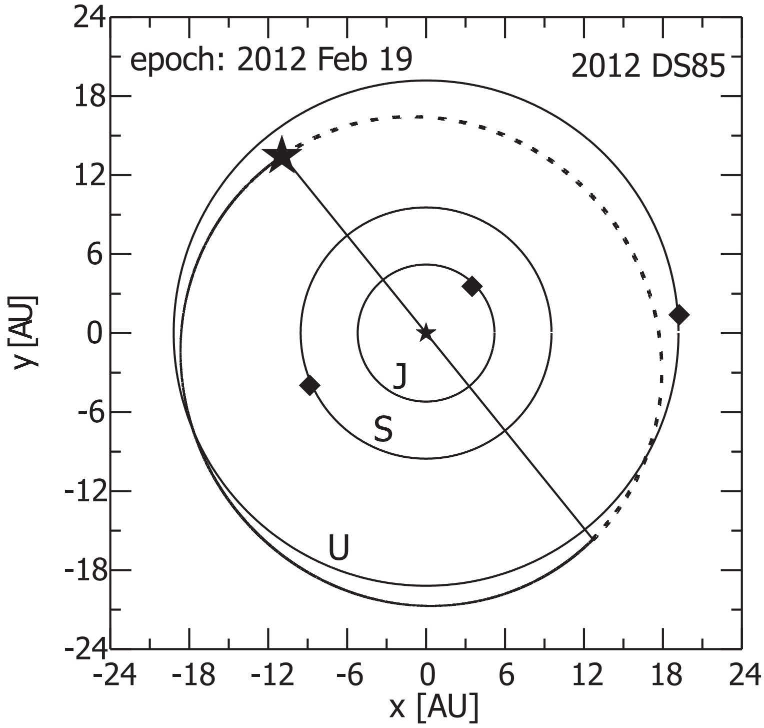

Fig. 2. The orbit of 2012 DS85 in the ecliptic plane. Positions of the asteroid and planets are presented for the date of discovery, 2012-02-19 = JD2455976.5. The dashed line denotes the part of the orbit below the ecliptic plane.

Table 3. The orbit of 2012 DS85 calculated with the OrbFit software with the 1σ errors (r.m.s.) of the parameters.

Epoch 2012 March 14.0 TT = JDT 2456000.5, r.m.s. = 0.519″					
a	e	i	Ω	ω	M
AU		deg	deg	deg	deg
18.8997	0.1180	16.7488	128.9712	309.8736	40.8397
± 0.0754	± 0.0306	± 0.0459	± 0.0007	± 14.6446	± 9.9929

its actual orbit calculated including the latest available positions. Table 3 presents the orbit computed by us using the OrbFit software v. 4.2 [3]. This new version includes a new error model of Chesley et al. (2010). The NEODyS and the OrbFit softwares are used for debiasing the star catalog and the error model with the assumed astrometric errors computed from the tests according to the mentioned paper. The relativistic effects, as well as perturbations from Ceres, Pallas, Juno and Vesta, are taken into account. Table 3 shows that the computed orbital elements of 2012 DS85 have small uncertainties, probably due to a good accuracy of observations.

With the OrbFit software from all observations we also computed a value of

[3] http://adams.dm.unipi.it/~orbmaint/orbfit/

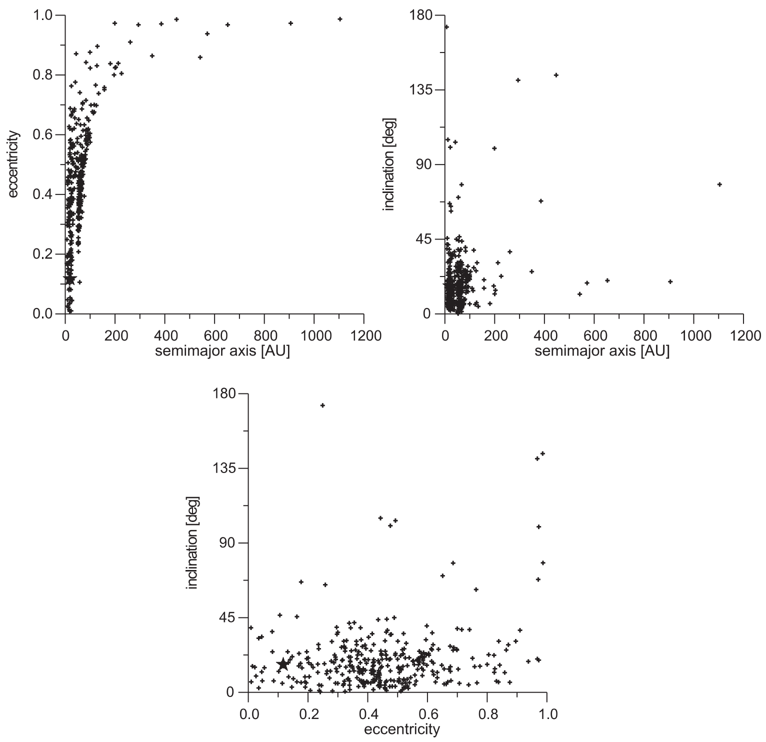

Fig. 3. Positions of all 353 known Centaurs and Scattered-Disk Objects (SDOs) in the MPC list updated on 2012-06-04. The asteroid 2012 DS85 is marked by a star symbol.

$H = 9.429$ mag, with the r.m.s. $= 0.316$ mag. Using a typical albedo of 0.08 for Centaurs and TNOs (Moullet et al. 2011), we find that the diameter of the asteroid is about 61 km.

3.2. The asteroid 2012 DS85 in the a vs. e phase space of the Centaurs.

According to the definition of MPC, Centaurs are objects with perihelia beyond the orbit of Jupiter and semimajor axes inside the orbit of Neptune. The Centaurs and the Scattered-Disk Objects are counted together.[4] In Figure 3 the dependencies between the semimajor axes a, eccentricities e and inclinations i of Centaurs and SDOs are plotted. The semimajor axes all are between 6.375 AU and 1104 AU. It is interesting that four Centaurs and SDOs are moving in retrograde orbits.

Figure 4 contains the same dependencies but only for 185 Centaurs and SDOs with semimajor axes smaller than 50 AU. Only one of these asteroids has eccentricity > 0.8. Between all 353 Centaurs and SDOs we find 24 with such eccentricities. The asteroid 2012 DS85 lies inside the main group of Centaurs with a small value of inclination.

[4] http://www.minorplanetcenter.net/iau/lists/Centaurs.html

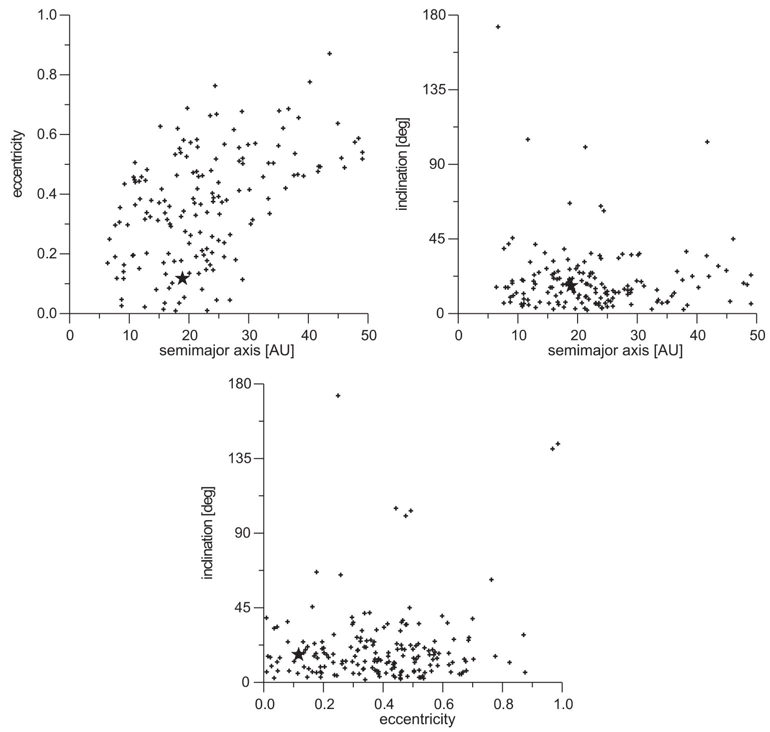

Fig. 4. The same as in Figure 3 but for 185 Centaurs and SDOs with semimajor axes smaller than 50 AU.

Table 4. Close approaches of 2012 DS85 with Saturn.

Time of approach (UT)	Minimum distance (AU)
1816-12-25.76	9.605
1909-04-04.79	8.755
2002-05-19.88	8.039
2094-09-21.05	8.334
2186-07-25.48	9.943

3.3. Time evolution of orbital elements of 2012 DS85

The ± 200 year integrations from now, i.e. between 1800 and 2200, show that our asteroid has no close approaches with planets. Only some approaches to Saturn are found but they are not closer than 8 AU (Table 4). This means that 2012 DS85 moves in a stable orbit.

Figure 5 shows that the orbital elements of 2012 DS85 change only in the small ranges: semimajor axis (18.75÷18.99) AU, eccentricity (0.11÷0.12), inclination (16.72÷16.79) degrees, longitude of the ascending node (128.8÷129.2) degrees. Only the argument of perihelion regularly changes its value between 0 and 360 degrees with a period of about 82 years. The orbital elements of the two Centaur asteroids discovered by us, 2012 DS85 and 2009 HW77 have similar orbital elements: semimajor axes 18.9 and 21.4 AU, eccentricities 0.12 and 0.4, and incli-

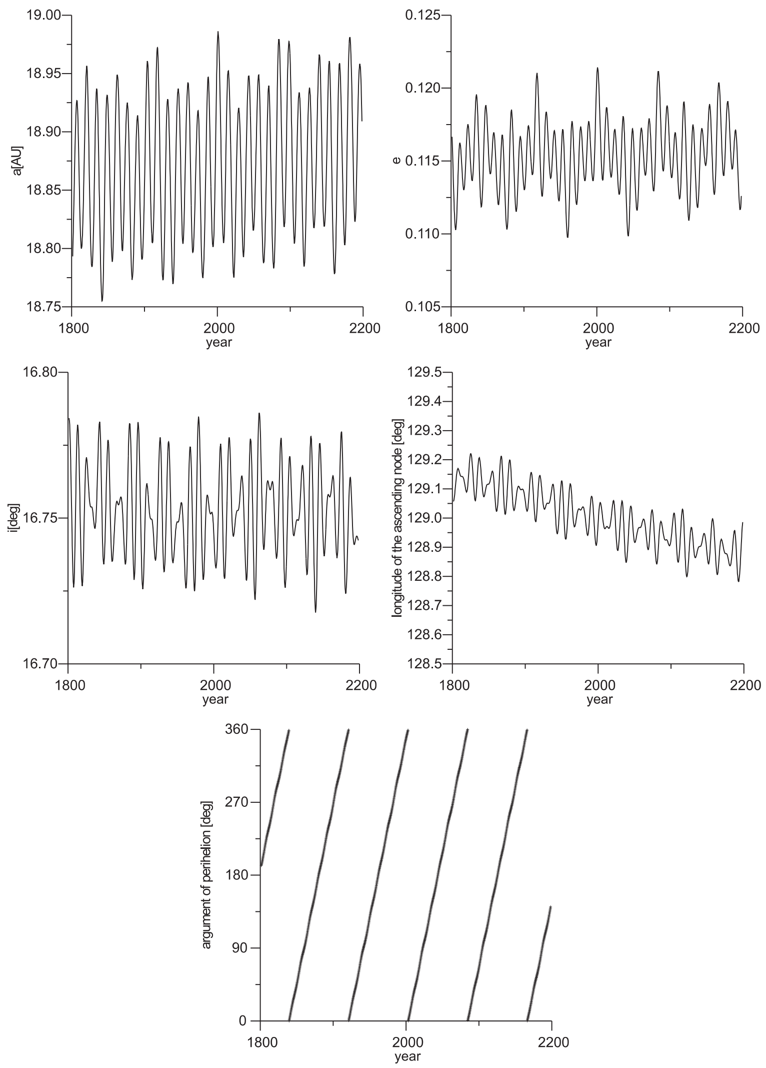

Fig. 5. Time evolution of the orbital elements of 2012 DS85 between 1800 and 2200.

nations 17 and 18 degrees, respectively. Both Centaurs have no close approaches with planets and have stable motion. Probably both of them belong to the same group of Centaurs (Wlodarczyk et al. 2011).

4. EPHEMERIDES FOR THE NEXT 50 YEARS

During the next 50 years there are only four yearly observational windows when the asteroid 2012 DS85 will be brighter than 22 mag. Table 5 lists the dates of observation, positions on the sky (right ascension and declination), magnitudes, solar elongations and the sky-plane errors. Asteroid will be well visible in the northern hemisphere. The sky-plane errors have only about several arcmin values, and the asteroid should be easily observable with big telescopes.

Table 5. Ephemerides of the asteroid 2012 DS85 for its visibility in 2013–2016. The coordinates (J2000) for a geocentric observer are given.

Date (UTC)	RA h m s	DEC ° ′ ″	mag	Solar elong. deg	Sky-plane error arcmin
2013 Jan 08	9 11 59.477	+17 42 37.59	21.9	+152.6	1.810
2013 Jan 18	9 10 22.124	+17 52 47.95	21.9	+163.1	1.783
2013 Jan 28	9 08 36.518	+18 03 21.20	21.8	+173.6	1.740
2013 Feb 07	9 06 47.531	+18 13 54.24	21.8	–175.3	1.686
2013 Feb 17	9 05 00.226	+18 24 03.86	21.9	–164.9	1.626
2013 Feb 27	9 03 19.749	+18 33 28.25	21.9	–154.4	1.565
2014 Jan 23	9 32 00.869	+17 50 52.84	21.9	+162.8	5.872
2014 Feb 02	9 30 17.458	+18 02 08.06	21.8	+173.0	5.776
2014 Feb 12	9 28 30.457	+18 13 14.51	21.8	–174.7	5.657
2014 Feb 22	9 26 44.898	+18 23 47.70	21.9	–164.8	5.527
2015 Feb 07	9 51 34.278	+17 52 05.90	21.9	+172.2	11.931
2015 Feb 17	9 49 49.300	+18 03 39.58	21.9	–173.7	11.753
2015 Feb 27	9 48 05.360	+18 14 31.03	21.9	–164.5	11.552
2016 Feb 12	10 12 24.163	+17 33 52.88	21.9	+171.3	20.024
2016 Feb 22	10 10 41.173	+17 45 46.91	21.9	–172.6	19.789

Table 6. Catalog of astrometric and photometric data for the asteroid 2012 DS85 obtained with the VATT.

Object	Date (UTC)	RA	DEC	Magnitude
K12D85S	C2012 02 19.31321	08 41 49.69	+18 20 37.6	22.0 R
K12D85S	C2012 02 19.31769	08 41 49.65	+18 20 37.9	21.7 R
K12D85S	C2012 02 19.32218	08 41 49.66	+18 20 38.7	21.9 R
K12D85S	C2012 02 19.32667	08 41 49.59	+18 20 38.6	21.9 R
K12D85S	C2012 02 19.33116	08 41 49.51	+18 20 38.8	21.8 R
K12D85S	C2012 02 21.31192	08 41 29.78	+18 22 24.6	21.9 R
K12D85S	C2012 02 21.31640	08 41 29.73	+18 22 24.9	21.7 R
K12D85S	C2012 02 21.32089	08 41 29.71	+18 22 25.3	21.9 R
K12D85S	C2012 02 21.32538	08 41 29.66	+18 22 25.6	21.8 R
K12D85S	C2012 02 21.32987	08 41 29.61	+18 22 25.8	21.9 R
K12D85S	C2012 02 22.34160	08 41 19.69	+18 23 19.6	21.5 R
K12D85S	C2012 02 22.35381	08 41 19.52	+18 23 20.1	21.5 R
K12D85S	C2012 02 22.36278	08 41 19.49	+18 23 20.6	21.6 R
K12D85S	C2012 02 24.30106	08 41 00.88	+18 25 01.5	21.7 R
K12D85S	C2012 02 24.31005	08 41 00.78	+18 25 02.0	21.4 R
K12D85S	C2012 02 24.31454	08 41 00.70	+18 25 02.6	21.6 R
K12D85S	C2012 02 26.34992	08 40 41.71	+18 26 47.1	21.8 R
K12D85S	C2012 02 26.35440	08 40 41.64	+18 26 47.4	21.9 R
K12D85S	C2012 02 26.35889	08 40 41.61	+18 26 47.5	21.8 R
K12D85S	C2012 02 26.36338	08 40 41.58	+18 26 47.3	21.8 R
K12D85S	C2012 02 26.37011	08 40 41.52	+18 26 48.3	21.8 R
K12D85S	C2012 02 26.37236	08 40 41.48	+18 26 48.3	21.7 R
K12D85S	C2012 02 26.38134	08 40 41.40	+18 26 48.4	21.8 R
K12D85S	C2012 02 27.35181	08 40 32.51	+18 27 37.4	21.8 R

Table 6. (continued)

Object	Date (UTC)	RA	DEC	Magnitude
K12D85S	C2012 02 27.35628	08 40 32.48	+18 27 37.6	21.9 R
K12D85S	C2012 02 27.36078	08 40 32.41	+18 27 37.9	21.9 R
K12D85S	C2012 02 27.36751	08 40 32.38	+18 27 38.1	21.8 R
K12D85S	C2012 02 27.37425	08 40 32.35	+18 27 38.6	21.8 R
K12D85S	C2012 02 27.37873	08 40 32.31	+18 27 38.7	21.7 R
K12D85S	C2012 02 27.38322	08 40 32.25	+18 27 39.0	21.9 R
K12D85S	C2012 04 16.18120	08 36 52.48	+18 53 31.0	21.5 R
K12D85S	C2012 04 16.18689	08 36 52.49	+18 53 31.1	21.6 R
K12D85S	C2012 04 17.15737	08 36 53.43	+18 53 41.3	21.8 R
K12D85S	C2012 04 17.16186	08 36 53.44	+18 53 41.4	21.8 R
K12D85S	C2012 04 17.16411	08 36 53.44	+18 53 41.4	21.7 R
K12D85S	C2012 04 17.16635	08 36 53.44	+18 53 41.6	22.0 R
K12D85S	C2012 04 17.17084	08 36 53.45	+18 53 41.7	21.2 R
K12D85S	C2012 04 17.17532	08 36 53.45	+18 53 41.8	21.7 R
K12D85S	C2012 04 17.18206	08 36 53.46	+18 53 41.6	21.6 R
K12D85S	C2012 04 18.18089	08 36 54.67	+18 53 51.4	21.6 R
K12D85S	C2012 04 18.18312	08 36 54.69	+18 53 51.1	21.7 R
K12D85S	C2012 04 18.18762	08 36 54.69	+18 53 51.5	21.7 R
K12D85S	C2012 04 18.19884	08 36 54.71	+18 53 51.6	21.6 R
K12D85S	C2012 04 19.15193	08 36 56.06	+18 54 00.1	21.5 R
K12D85S	C2012 04 19.15642	08 36 56.10	+18 53 59.6	21.5 R
K12D85S	C2012 04 19.15867	08 36 56.11	+18 53 59.8	21.5 R
K12D85S	C2012 04 19.16541	08 36 56.15	+18 53 59.7	21.3 R
K12D85S	C2012 04 19.17437	08 36 56.18	+18 53 59.9	21.5 R
K12D85S	C2012 04 19.17887	08 36 56.17	+18 53 59.7	21.2 R
K12D85S	C2012 04 19.22808	08 36 56.20	+18 54 00.3	21.6 R
K12D85S	C2012 04 19.23706	08 36 56.21	+18 54 00.3	21.3 R
K12D85S	C2012 04 21.17528	08 36 59.72	+18 54 14.7	21.5 R
K12D85S	C2012 04 21.18287	08 36 59.73	+18 54 14.9	21.3 R
K12D85S	C2012 04 22.15168	08 37 01.85	+18 54 20.0	21.4 R
K12D85S	C2012 04 22.15547	08 37 01.86	+18 54 20.4	21.7 R
K12D85S	C2012 04 22.15926	08 37 01.87	+18 54 20.6	21.2 R
K12D85S	C2012 04 22.16685	08 37 01.88	+18 54 20.7	21.2 R
K12D85S	C2012 04 22.21964	08 37 02.00	+18 54 20.8	20.9 R
K12D85S	C2012 04 22.22342	08 37 02.01	+18 54 20.7	21.9 R
K12D85S	C2012 04 22.22723	08 37 02.02	+18 54 20.7	21.4 R
K12D85S	C2012 04 23.15677	08 37 04.25	+18 54 25.5	21.6 R
K12D85S	C2012 04 23.16057	08 37 04.24	+18 54 25.7	21.7 R
K12D85S	C2012 04 23.16435	08 37 04.26	+18 54 25.8	21.5 R
K12D85S	C2012 04 23.16815	08 37 04.31	+18 54 25.9	21.4 R
K12D85S	C2012 04 23.17194	08 37 04.31	+18 54 25.9	21.3 R
K12D85S	C2012 04 25.16338	08 37 09.72	+18 54 33.1	21.3 R
K12D85S	C2012 04 25.17097	08 37 09.76	+18 54 33.4	21.5 R

5. CONCLUSIONS

1. On the 1.8 m telescope of the Vatican Observatory (VATT) for the asteroid 2012 DS85 we have assembled 67 precise astrometric positions (the errors $< 0.519''$).

2. From these positions the orbit of the asteroid is calculated. The asteroid belongs to the group of Centaurs.

3. The orbit of the asteroid, combined with its apparent brightness, gives the absolute magnitude $H = 9.43$ and the diameter of about 61 km, taking an albedo value of 0.08.

4. The ephemerides of the asteroid are calculated from 2013 to 2016 with the positional uncertainty of about 2–20′. Thus, its rediscovery in the next opposition should not be problematic.

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