A&A 463, 1197–1199 (2007)
DOI: 10.1051/0004-6361:20066518

Astronomy & Astrophysics

Photometric and spectroscopic observations of (132524) 2002 JF$_{56}$: fly-by target of the New Horizons mission[★]

C. Tubiana[1], R. Duffard[1], L. Barrera[2], and H. Boehnhardt[1]

[1] Max Planck Institute for Solar System Research, Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany
e-mail: `[tubiana;duffard;boehnhardt]@mps.mpg.de`
[2] Universidad Metropolitana de Ciencias de la Educación, Santiago, Chile
e-mail: `lbarrera@umce.cl`

Received 6 October 2006 / Accepted 14 November 2006

ABSTRACT

Aims. The asteroid (132524) 2002 JF$_{56}$ was the distant fly-by target of the New Horizons spacecraft on June 13, 2006. To further enhance our knowledge of this asteroid and facilitate the cross-calibration of the spacecraft instruments, ground based observations of the asteroid were performed in May 2006 at ESO VLT.

Methods. Photometry and spectroscopy of (132524) 2002 JF$_{56}$ were performed: a set of R filter broadband images and reflectance spectra were taken with FORS2 of the ESO VLT for a total of three nights (May 25, 30 and 31, 2006). Each observational cycle spans a time interval of about one hour per night. The observations were performed about two weeks before the fly-by, when the asteroid was at a heliocentric distance of 2.5 AU.

Results. The reflectance spectra of 2002 JF$_{56}$ resemble those of S-type asteroids. From the photometry of the asteroid, an effective diameter of about 2.3 km is estimated and a lower limit for the axis-ratio of (1.19 ± 0.02) is determined.

Key words. minor planets, asteroids – Solar system: general

1. Introduction

On October 29, 1991, the Galileo spacecraft carried out the first ever fly-by of an asteroid, (951) Gaspra (Veverka et al. 1994). Less than two years later, on August 28, 1993, Galileo encountered a second main-belt asteroid, (243) Ida; both asteroids are classified as S-type. The biggest surprise during Galileo's fly-by of (243) Ida was the discovery that the asteroid has a 1.5 km-wide satellite, Dactyl (Granahan 2002). After this discovery, more than 20 asteroid satellites have been discovered by ground-based observations using optical and radar techniques (Merline et al. 2002). The first encounter with a C-type asteroid took place on June 27, 1997, when the NEAR Shoemaker spacecraft flew by the main-belt asteroid (253) Mathilde (Cheng 2004). In the aforementioned cases, the asteroids were secondary targets of the main missions (Galileo to Jupiter and NEAR Shoemaker to the asteroid (433) Eros). During its journey to the comet 67P/Churyumov-Gerasimenko, the ESA spacecraft Rosetta is scheduled to fly-by two main-belt asteroids: (2867) Steins in September 2008 and (21) Lutetia in July 2010 (Barucci et al. 2005). Spacecraft fly-bys are ideal to obtain reconnaissance data of asteroids even if remote sensing during the fly-by is limited by two important factors, the distance of the observed object and the short duration of the encounter (Farquhar et al. 2002). Even if some limitations and difficulties exist, ground-based observations are important since a direct comparison with space-based data is possible. This is instrumental to draw firmer conclusions between the limited number of spacecraft mission targets and the much larger sample of asteroids observed from Earth. The NASA New Horizons will be the first spacecraft to visit Pluto and Charon. During the cruise phase, on June 13, 2006, the spacecraft passed at nearly 100 000 km from the asteroid (132524) 2002 JF$_{56}$. The primary purpose of this distant fly-by was to test optical navigation and moving target tracking capabilities. The mission requested Earth-based support observations for comparison and for characterization of the physical properties of the widely unexplored asteroid (Olkin et al. 2006). For this reason, ground-based observations of (132524) 2002 JF$_{56}$ were performed at the ESO-VLT almost two weeks before the distant fly-by. The asteroid (132524) 2002 JF$_{56}$ is a Main Belt asteroid with semi-major axis a = 2.605 AU, eccentricity e = 0.271 and inclination i = 4.163°.

The aim of our photometric and spectroscopic observations of this object is the determination of physical parameters (diameter and shape) and the taxonomic classification (indicative for the surface composition). The results are presented in this paper. In the next section we describe the observing and reduction procedures. The analysis of the data, extraction of the relevant parameters and identification of taxonomic type are presented in Sect. 3, as well as a brief discussion of the obtained results. We conclude with a review of our main results.

2. Observations and data reduction

Images and low resolution spectra of (132524) 2002 JF$_{56}$, in the visible wavelength range, were obtained on May 25, 30 and 31, 2006 with the FORS2 instrument at the 8.2 m Very Large Telescope (VLT) UT1 (Antu). FORS2 (`http://www.eso.org/instruments/fors/index.html`) is one of the two visual and near UV FOcal Reducer and low dispersion Spectrographs for the Very Large Telescope (VLT) of the European Southern Observatory (ESO). It is equipped with a detector consisting of

---

[★] Based on observations performed at the European Southern Observatory, Chile (ESO Programme 77.C-0609).

Table 1. Observational circumstances for (132524) 2002 JF$_{56}$: heliocentric distance (r), geocentric distance (Δ), phase angle (ϕ), predicted visual magnitude (V), number of images and spectra taken, typical seeing and sky condition (PH = photometric, CL = clear).

	UT	r [AU]	Δ [AU]	ϕ [°]	V [mag]	Images/Spectra	Seeing/Sky
2006.05.25	23:30	2.512	1.700	16.834	19.2	23/2	0.4–0.6/PH
2006.05.30	23:20	2.497	1.732	18.403	19.3	4/2	0.9–1.1/CL
2006.05.31	23:10	2.494	1.739	18.696	19.3	4/2	0.7–1.0/PH

a mosaic of two 2k × 4k MIT CCD (15 μm pixels). The image scale in the default readout mode (2 by 2 binning) is 0.25″/pixel in the standard resolution mode, providing a field of view of 6.8′ × 6.8′. The observations were performed with the telescope tracking at the proper motion rate of the asteroid. Table 1 summarizes the photometric and spectroscopic circumstances in the three nights of observations. The observations of (132524) 2002 JF$_{56}$ span a time interval of about one hour per night.

2.1. Photometry

A total of 31 images of the asteroid were taken in the R broadband filter ($\lambda_{\rm eff}$ = 6550 Å, $FWHM$ = 1650 Å) with an exposure time t = 10 s. In the first night 23 images were obtained, while on the second and third nights 4 images were obtained. Bias, flat-fields and photometric standard star fields were taken each night. The images were reduced using standard techniques of bias subtraction, flat field correction (with a super-flat field created from the night exposures), exposure time normalization and sky background subtraction. For the flux calibration, the photometric coefficients (zero point, extinction coefficient and color term) were determined using several standard star fields taken at different airmass.

2.2. Spectroscopy

Spectroscopy was obtained in between the R filter imaging. Two spectra per night were taken using grism 150I ($\lambda_{\rm cent}$ = 7200 Å, dispersion = 3.45 Å/pix). On May 25 a 1.3″ slit was used while on May 30 and 31 a 1.0″ slit was used. The slit was placed parallel to the direction of proper motion of the asteroid. For calibration purposes, spectra of solar analogue stars were taken (SA102-108, SA110-361, SA112-133, SA115-271, Landolt 1992) at similar air masses as the asteroid's spectra. For each night, bias frames, spectral dome flat fields and arc lamp spectra were obtained. The measurements of the object were split into two exposures at two different slit positions A and B, 20″ apart. By subtracting spectrum A from B and B from A, a very accurate background removal is achieved. Standard methods for spectra reduction and extraction were used and images were then divided by the solar analogue SA102-108. The spectra were normalized to 1 at 5500 Å and shifted for clarity; the final results are shown in Fig. 1 (top panel). To look for a possible variation between the spectra, a polynomial fit is used and the ratios between the three different nights are shown in Fig. 1 (bottom panel).

In each night of observations at least two solar analogues were observed in order to estimate the quality of the night. The ratios between the spectra of the solar analogues for each night are flat and show no substantial variation. The influence of different analogs on the resulting spectra is checked showing differences in the continuum slopes smaller than 1%/10^3 Å.

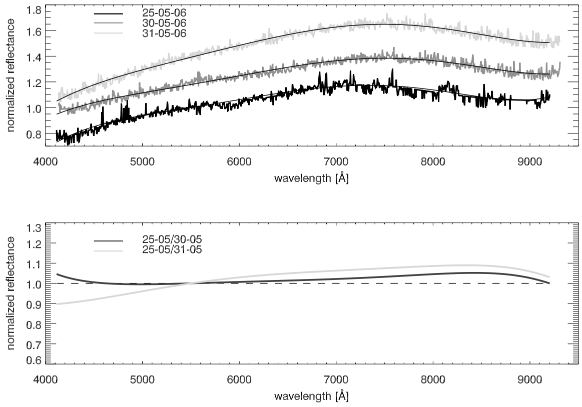

Fig. 1. *Top panel*: reflectance spectra for (132524) 2002 JF$_{56}$ obtained at ESO-VLT on May 25, 30 and 31, 2006. The spectra, normalized at 5500 Å and shifted for clarity, resemble those of S-type asteroids. *Bottom panel*: ratio of the reflectance spectra with to the one obtained on May 25, 2006.

3. Results and conclusions

The reflectance spectra of (132524) 2002 JF$_{56}$ correspond to that of S-type asteroids. Small variations in the spectra taken in the three nights are noticeable. These variations could be due to the rotational phase of the object. As the rotational period of the object is not known, it is not possible to ensure that the entire surface has been observed.

The single magnitude measurements are summarized in Table 2 and the photometry (magnitude vs. time) is plotted in Fig. 2, where the different symbols refer to the different nights of observations. An average magnitude in the R filter (λ_R = 6380 Å) of m_{abs} = (19.20 ± 0.01) mag is obtained from the data. On May 25, a slight decrease in the brightness of the asteroid is measured over the 1.4 h time interval, while on May 30, the magnitude slightly decreases with time. On May 31, instead, it is rather constant around the value m_{abs} = (19.22 ± 0.01) mag.

For the determination of the effective diameter of the asteroid, two approximations of the phase function were applied to the magnitude (m_{abs}): one, generally used for comets at small or moderate phase angles (Lamy et al. 2004), and one adopted by IAU for asteroids (Meeus 1998), which is also used at high phase angles. In the case of the asteroid, observed at α = 18°, both phase corrections give a similar value of H (H_1 = (15.10 ± 0.01) mag and H_2 = (15.21 ± 0.01) mag, where H_1 and H_2 are the magnitudes calculated using the first and the second phase function correction, respectively). Since there are no precise measurements of the asteroid's albedo, we consider a typical range for S-type asteroids of p = (0.15–0.30) (Bus 1999). Using this range, the observational parameters reported in Table 1 and the asteroid's magnitude (H), we estimated a range of variation of the asteroid's diameter in the R filter $d_{\rm eff}$ = (1.85–2.77) km (Swamy 1996). Thus an average value of 2.3 km is a good estimate of the diameter of (132524) 2002 JF$_{56}$. The error associated with the single value of the diameter is about 1%, but

Table 2. Photometric data of (132524) 2002 JF$_{56}$: UT start time, absolute magnitude $m_{\rm abs}$ and error on the absolute magnitude $\sigma_{\rm mag}$ are reported for each exposure performed.

Time [UT]	$m_{\rm abs}$ (mag)	$\sigma_{\rm mag}$ (mag)
night 1: 25.05.06		
23:38:26	19.10	0.03
23:39:42	19.07	0.03
23:41:10	19.10	0.03
23:41:53	19.09	0.03
23:42:39	19.12	0.03
23:43:23	19.10	0.03
23:44:08	19.12	0.03
23:44:50	19.09	0.03
23:45:36	19.10	0.03
23:46:19	19.13	0.03
23:47:06	19.10	0.03
23:47:49	19.13	0.03
23:50:50	19.11	0.03
23:51:34	19.10	0.03
23:52:21	19.11	0.03
23:53:04	19.11	0.03
23:53:48	19.08	0.03
23:54:31	19.11	0.03
23:55:17	19.12	0.03
23:59:34	19.12	0.03
00:00:38	19.13	0.03
00:51:17	19.18	0.03
00:52:12	19.18	0.02
night 2: 30.05.06		
23:25:20	19.30	0.03
23:26:08	19.29	0.03
00:19:11	19.22	0.02
00:19:59	19.18	0.02
night 3: 31.05.06		
23:15:27	19.23	0.03
23:16:14	19.16	0.02
00:10:56	19.23	0.02
00:11:44	19.23	0.02

the uncertainty in the albedo results in a large uncertainty in the asteroid's diameter. Assuming that the asteroid is a two axial ellipsoid with semi-axis a and b, using the difference in magnitude shown in Fig. 2, we estimate a lower limit for the axis ratio of $a/b = (1.19 \pm 0.02)$.

From ground-based observations (132524) 2002 JF$_{56}$ is classified as an S-type asteroid. The axis-ratio determined shows that during the time of observation no large changes of the asteroid's cross-section took place. The estimated effective diameter is in agreement with that obtained by the New Horizons mission (approximately 2.5 km) observations (`http://pluto.jhuapl.edu/gallery/missionPhotos/pages/asteroid.html`). A determination of the rotational period may be possible by combining set of photometric data from different observers.

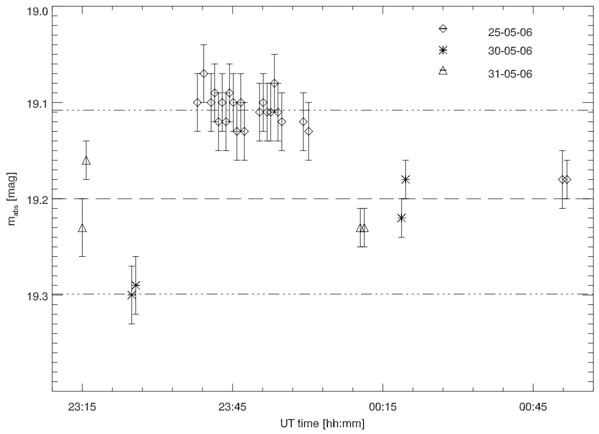

Fig. 2. Magnitude vs. time for (132524) 2002 JF$_{56}$. Each symbol corresponds to a different night. The dashed lines represent the brightest and faintest magnitude and the mean value.

After the final definition of the cruise trajectory of a mission, the possible asteroid targets can be defined. Ground-based observations are useful to calibrate the spacecraft's instrument for the fly-by and they allow a direct comparison between ground- and space-based observations. The key requirement is the development of efficient "target of opportunity" searches, combining the spacecraft trajectory and asteroid databases.

Acknowledgements. Thanks to Sanja Danilovic (MPS, Katlenburg-Lindau, Germany) who provided the computer facilities to perform the spectroscopic data reduction and to Richard Binzel (MIT Cambridge, USA) who helped to prepare the VLT observations on very short notice.

References

Barucci, M. A., Fulchignoni, M., Fornasier, S., et al. 2005, A&A, 430, 313

Bus, S. J. 1999, Ph.D. Thesis, Massachusetts Institute of Technology, Massachusetts

Cheng, A. F. 2004, Adv. Space Res., 33, 1558

Farquhar, R., Kawaguchi, J., Russell, C., et al. 2002, Asteroids III, ed. W. F. Bottke Jr., A. Cellino, P. Paolicchi, & R. P. Binzel (Tucson: University of Arizona Press), 367

Granahan, J. 2002, J. Geophys. Res. (Planets), 107, 20

Lamy, P. L., Toth, I., Fernandez, Y. R., & Weaver, H. A. 2004, Comets II, ed. M. C. Festou, H. U. Keller, & H. A. Weaver (Tucson: University of Arizona Press), 745, 223

Landolt, A. U. 1992, AJ, 104, 340

Meeus, J. 1998, Astronomical algorithms, 2nd edn., ed. J. Meeus (Richmond, VA: Willmann-Bell)

Merline, W. J., Weidenschilling, S. J., Durda, D. D., et al. 2002, Asteroids III, ed. W. F. Bottke Jr., A. Cellino, P. Paolicchi, & R. P. Binzel (Tucson: University of Arizona Press), 289

Olkin, C. B., Reuter, D., Lunsford, A., Binzel, R. P., & Stern, S. A. 2006, 38th Meeting of the AAS Division for Planetary Sciences 8–13 October 2006, Pasadena, CA, USA

Swamy, K. S. Krishna 1996, Physics of comets, World Scientific series in astronomy and astrophysics (Singapore: World Scientific), 2nd Ed.

Veverka, J., Belton, M., Klaasen, K., & Chapman, C. 1994, Icarus, 107, 2