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The EURONEAR Lightcurve Survey of Near Earth Asteroids 2017-2020

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Abstract This is the fourth data paper publishing lightcurve survey work of 52 Near Earth Asteroids (NEAs) using 10 telescopes available to the EURONEAR network between 2017 and 2020. Forty six targets were not observed before our runs (88% of the sample) but some of these were targeted during the same oppositions mainly by Brian Warner. We propose new periods for 20 targets (38% of the sample), confirming published data for 20 targets, while our results for 8 targets do not match published data. We secured periods for 15 targets (29% of the sample), candidate periods for 23 objects (44%), tentative periods for 11 asteroids (21%), and have derived basic information about 3 targets (6% of the sample). We calculated the lower limit of the ellipsoid shape ratios a/b for 46 NEAs (including 13 PHAs). We confirmed or suggested 4 binary objects, recommending two of them for follow-up during future dedicated campaigns.

Keywords Near Earth Asteroids · Lightcurves · Rotation Periods · Physical Properties

1 Introduction

Physical observations of Near Earth Asteroids (NEAs) and Potentially Hazardous Asteroids (PHAs) are essential to be performed, in order to improve our knowledge about the formation and evolution of these important asteroid populations, while taking into account their possible accessible resources and potential risks.

From a total of 27,311 NEAs known today (18 Jan 2022), there are only 1,998 objects that have any lightcurve information (7%), according to the LCDB December 2021 database[1]. Most observers are amateur astronomers who enjoy unlimited time using their own small telescopes (typically 30-60 cm), such as Brian D. Warner (the world leader who has observed more than one thousand NEAs) and Robert Stephens in the USA, Peter Birtwhistle in the UK, Amadeo Aznar Macías in Spain, Luca Buzzi in Italy, Julian Oey in Australia, among others. Additionally, a few professional astronomers use larger (typically one meter class) telescopes, being constrained by the scarce available time obtained through competition, among which Petr Pravec based in the Czech Republic, Adrian Galad in Slovakia, Raoul Behrend in Switzerland, Thomas Kwiatkowski from Poland, David Polishook from Israel, Filipe Monteiro in Brasil, and a few others. Most of their work has been published in the Minor Planet Bulletin (published since 1973 by ALPO, currently edited by Richard P. Binzel), with a few authors choosing to present their results in other journals or conferences.

Since 2014, the EURONEAR project[2] has been increasing the physical knowledge of NEAs based mainly on photometric and spectroscopic observations, besides astrometric observations and data mining aimed to improve the orbital knowledge of NEAs. This is the fourth and last in a series of data papers publishing rotation periods of NEAs observable between 2017 and 2020 within the EURONEAR network. Eight ING students, one ULL student, four Chilean students and two Romanian PhD students (all included as co-authors) were involved in the research presented in this paper. It follows the previous survey work of Aznar et al. [3] and Vaduvescu et al. [36, 39] who published results of 151 NEA lightcurves observed between 2014 and 2016. Lightcurves of another 18 NEAs were published within the same EURONEAR collaboration by Sonka et al. [28–35], Vaduvescu et al. [37, 38], Aznar et al. [4,6], and Birlan et al. [9]. Together, these works add together 215 NEAs observed with 21 telescopes within the EURONEAR network, which represents about 10% of the entire NEA lightcurve published work.

2 The Observing Facilities

In this work we publish data collected with 10 telescopes adding a total of 657 observing hours. We briefly present each facility in order of their size, listing their main characteristics in Table 1.

2.1 The Isaac Aznar Observatory 0.36 m Telescope in Spain

The Isaac Aznar Observatory (IAO) is privately owned by the Spanish amateur astronomer Amadeo Aznar. It is located in Alcublas, Valencia province, at 900 m above the sea level, in one of the darkest night-sky of the Iberian Peninsula (limiting magnitude 21.8 mag/arcsec^2). The optical system consists of a remotely controlled 0.36 m Schmidt-Cassegrain F/10 Meade LX200 telescope. The CCD camera is a SBIG STL 1001e with adaptive optics and CCD 1024 × 1024 pixels of size 24.6 μm, resulting in $1.44''$/pixel and a square $25'$ field. The camera holds

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[1] https://www.minorplanet.info/php/lcdbsummaryquery.php

[2] www.euronear.org

broad band Astrodon Sloan r and Johnson V filters, working at -20 C with cooled water in the summer. Typical seeing at IAO is around $1''$. The total contribution of the IAO-T36 telescope was 141 hours.

2.2 The Blue Mountain Observatory 0.36 m Telescope in Australia

This private observatory is owned by the Australian amateur astronomer Julian Oey, who has become an ocasional EURONEAR collaborator since 2015. The observatory is located at 946 meters altitude in New South Wales, about 110 km West of Sydney, the observations benefiting from a dark sky as 21.4 mag/arcsec^2. One of the BMO telescopes is the remotely controlled F/5.9 Celestron SCT 0.36 m Schmidt Cassegrain telescope, equiped with the SBIG ST8XME camera with 9 μm 1530 × 1020 pixels resulting in image scale of $0.98''$/pixel and a field of $25' \times 16.7'$. Observations were made with a Clear filter. Typical seeing at Blue Mountain Observatory is $1.2''$. The total contribution of the BMO-T36 telescope was 19 hours.

2.3 The TAR3 0.4 m Telescope in Tenerife, Spain

The Telescopio Abierto Robótico (TAR) consists in a robotic network of three telescopes hosted in the same roll-off dome located at 2390 meters altitude at Teide Observatory (Tenerife, Canary Islands, Spain). The TAR3 telescope (used in this paper) is a Meade $16''$ telescope equipped with a FLI MicroLine E2V CCD47-10 camera with square 13μm 1024 × 1024 pixels. Combined with the F/6.3 focal reducer, TAR3 system gives a plate scale of $1.5''$/pix and a square field of view $25.6'$. The typical TAR seeing is around $2.5''$. The total contribution of the TAR3 telescope was 11 hours.

2.4 The Chakana 0.6 m Telescope in Chile

In June 2015, the Ckoirama Observatory (from the Kunza language, which means "twilight") became the first Chilean state-owned observatory located under desert skies, managed by the Astronomy Center (CITEVA) of the University of Antofagasta, Chile. The observatory is located on the plains of the Atacama desert, at 1010 m altitude 65 km to the South East of the city of Antofagasta. It is equipped with a PlaneWave Instruments CDK24 telescope (named Chakana) F/6.5 0.6 m diameter and a FLI ProLine 16801 camera 9 μm 4096 × 4096 pixels providing $0.47''$/pixel and a square $32.4'$ field. The typical seeing observed with the Chakana telescope is $1.5''$ [11]. The total contribution of the Chakana telescope was 59 hours.

2.5 The SARA-S 0.6 m Telescope in Chile

In 2010, the U.S.-based university consortium Southeastern Association for Research in Astronomy (SARA) added the 0.6 m Boller & Chivens telescope formerly operated by Lowell at Cerro Tololo to the SARA network which owns two other telescopes, namely the 0.96 m telescope at Kitt Peak, Arizona and the 1 m Jacobus Kapteyn Telescope (JKT) at the Roque de los Muchachos in La Palma [16]. The SARA Cerro Tololo telescope is located 2151 m altitude and delivers image quality around FWHM $1.5''$ and occasionally subarcsecond seeing mostly in summer. At its F/13.5 Cassegrain focus the CCD camera FLI 2048 × 2048 and 24 μm pixels provides a pixel scale of $0.61''$/pixel and a square field $10.4'$. The telescope is remotely controlled by users using VNC protocols under Windows OS [2]. Typical seeing for SARA CTIO telescope is $1.5''$. The total contribution of the SARA-S telescope was 28 hours.

2.6 The OSN 0.9 m Telescope in Spain

This 0.91 m $F/8$ telescope is owned by the *Instituto de Astrofísica de Andalucía* (IAA-CSIC), being installed at the Sierra Nevada Observatory (OSN, South of Spain) at 2896 m altitude. At one of the Nasmyth foci sits the CCDT90 camera using a VersArray 13.5 μm 2048 pixels CCD providing $0.39''$/pixel and a square $13.2'$ field. The typical seeing in Sierra Nevada is around $1.5''$. We observed one target in clear filter using 2 × 2 binning which allowed only 6 s readout in slow mode. The total contribution of the OSN-T90 telescope was 23 hours.

2.7 The Wise 1.0 m Telescope in Israel

Founded in October 1971 as a collaboration between Tel Aviv University and the Smithsonian Institution, the Wise Observatory is a research laboratory owned by Tel-Aviv University in Israel. It is located at 5 km west of the town of Mitzpe Ramon in the Negev desert near the edge of the Ramon Crater, at an altitude of 875 m. The Boller and Chivens F/7 1 m diameter telescope (the largest at the site) is equipped with an SBIG STX-16803 camera with 9 μm 4096 × 4096 pixels providing $17.8'$ square field. The pixel size is $0.26''$/pixel, which gives an over-sampling of the imaged objects, and the optimal setup is by binning it 3 × 3 and to get pixel size of $0.78''$/pixel. The typical seeing at Wise Observatory is around $2.5''$. The total contribution of the Wise telescope was 18 hours.

Table 1: Technical characteristics of the telescopes and total observed time (ObsT column).

Observatory	Country	Telescope	Acronym	D (m)	F/D	Camera	Pixel (″)	FOV (′)	Seeing (″)	ObsT (h)
Isaac Aznar Observatory	Spain	IAO 36-cm	IAO-T36	0.35	10.0	SBIG STL 1001e	1.44	25.0	1.0	141
Blue Mountain	Australia	BMO 36-cm	BMO-T36	0.35	5.9	SBIG ST8XME	0.98	25 × 16.7	1.2	19
Teide Observatory	Spain	TAR3	TAR3	0.4	6.3	FLI MicroLine	0.68	25.6	2.5	11
Ckoirama	Chile	Chakana	Chakana	0.6	6.5	FLI ProLine 16801	0.47	32.4	1.5	59
Cerro Tololo	Chile	SARA 0.6-m	SARA-S	0.6	13.5	FLI	0.61	10.4	1.5	28
Sierra Nevada	Spain	OSN 0.9-m	OSN-T90	0.9	8.0	CCDT90	0.39	13.2	1.5	23
Wise Observatory	Israel	Wise 1-m	Wise	1.0	7.0	SBIG STX-16803	0.78	17.8	2.5	18
Las Campanas	Chile	Warsaw	Warsaw	1.3	2.8	OGLE-IV	0.52	8.9 × 17.7	0.6	107
Roque de los Muchachos	Spain	Mercator	Mercator	1.3	8.3	MAIA	0.28	9.4 × 14.1	0.8	79
Roque de los Muchachos	Spain	Isaac Newton	INT	2.5	3.3	WFC	0.33	10.0	1.2	172

2.8 The Warsaw 1.3 m Telescope in Chile

Opened in 1996, the Ritchey-Chretien F/2.8 1.3 m diameter Warsaw telescope is owned by Warsaw University, Poland, installed at Las Campanas Observatory in Chile, at 2275 m altitude. It is equipped with the mosaic camera OGLE-IV equiped with 32 E2V44-82 CCDs 2048 × 4096 pixels 0.26″/pixel providing 1.4 square degrees total field of view. For our photometric observations we used only central CCD number 11, providing a 8.9′ × 17.7′ field and binning 2 × 2 with 0.52″/pixel. The telescope used differential rates to track all targets. Typical seeing in Las Campanas is 0.6″ [22]. The total contribution of the Warsaw telescope was 107 hours.

2.9 The Mercator 1.2 m Telescope in La Palma

This 1.2 m $F/8.3$ telescope is operated by the Belgium Leuven University at *Roque de los Muchachos Observatory* (ORM) in La Palma, Canary Islands, Spain. At the tilted Cassegrain focus of the telescope sits the modern MAIA camera, a three-channel imager originally built for ESA's Eddington mission (later canceled), capable for simultaneous fast-cadence three-colour photometry *ugr* which provides the opportunity to check for colour variation along the lightcurves. The three MAIA frame-transfer CCDs consist each in 13.5 µm 2048 × 3072 pixels, at a scale of 0.28″/pixel, resulting in a rectangular 9.4′ × 14.1′ field. The Mercator telescope is capable of tracking at differential rates. The typical seeing at 2400 m altitude in La Palma is 0.8″. The total contribution of the Mercator telescope was 79 hours.

2.10 The Isaac Newton Telescope 2.5 m in La Palma

The 2.5 m Isaac Newton Telescope is owned by the Isaac Newton Group (ING), located at 2336 m altitude at the ORM observatory in La Palma, Canary Islands, Spain. At its $F/3.3$ prime focus is located the WFC mosaic camera consisting of four CCDs 13.5 µm 2048 × 4096 pixels resulting in 0.33″/pixel and 34′ field with a missing square 12′ in its NW corner. Many broad and narrow band filters are available, during our runs we used Sloan r. The telescope is capable of tracking at differential rates. For the fast-moving objects we used the central CCD4 square 10′ field (reading each image in 18 s in slow readout or 10 s in fast mode used in this work), while for slower moving objects we window the central CCD4 square 5′ (6 s readout in slow or 3 s in fast mode). The median ORM site seeing is 0.8″, while the INT median seeing is 1.2″. The total contribution of the INT telescope was 172 hours.

Throughout the whole project, we chose the filters based on the available set for each instrument, aiming to collect the most photons, taking into account filter throughput, CCD response and Moon phase. For the objects observed with more than one instrument, we applied small arbitrary data offsets to account for the colour difference, attempting the best curve fitting (smallest RMS). We always used Sloan r at the INT, Wise-T1 and Mercator (simultaneously with Sloan g), I filter at Warsaw, R or V filter at OSN-T90, V filter at IAO-T36, V filter at TAR3 telescope, the Luminance or no filter at SARA-S, and no filter at Chakana and BMO-T36 telescopes.

3 Image Processing and Data Reduction

The INT and Mercator raw images were reduced using in-house built IRAF scripts written by O. Vaduvescu which apply bias and flat field corrections. The IAO-T36, TAR3, OSN-T90 and most of SARA-S and Warsaw images were reduced by A. Aznar using CCDOps software[3] which applied bias and flat field. The BMO-T36 images were reduced by J. Oey who used CCDSoft v.5 software[4], taking into account bias, dark and flat field. The Wise data

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[3] http://www.company7.com/library/sbig/sbwhtmls/ccdopsv5.html

[4] http://www.company7.com/sbig/products/CCDSoftV5.html

reduction was reduced by the observer F. Pozo Nunez on site by applying bias, dark, flat field, astrometry and field distortion corrections, using IRAF in combination with Scamp and Swarp Astromatic[5] [8] and Astronomy.net[6] [17] routines. The reader is referred to [24] for further information about the data reduction.

We used *MPO Canopus*[7] Windows based software written by Brian D. Warner, to reduce the photometry of all targets. For all targets and sessions we used relative photometry based on up to 5 reference stars taken from SDSS [1], Pan-STARRS [10] or APASS [15] catalogs (in this order), retrieved via VizieR[8]. The Canopus reducers were A. Aznar, O. Vaduvescu, M. Predatu, R. Gherase and J. Oey.

4 The Observed NEAs and Results

Table 2 includes 52 objects observed during this campaign. Following our previous work [36,39], we present the data using the same conventions. Targets observed with different telescopes are given in separated lines. We list the NEA number or designation (marking in bold PHAs), the orbital class (APollo, AMor or ATen), absolute magnitude H, the observing date or interval (in format DD/MM/YY), telescope, apparent magnitude V (as given by the MPC ephemerides), sky proper motion μ (in $''$/min), exposure time (in seconds), total observed time (rounded up in hours), mean reduced magnitude $H(\alpha)$ (corresponding to the observed filter), phase angle interval α (in degrees), derived semi-major axis ratio a/b, measured amplitude, derived rotation periods P (in hours), and the Fourier fit error σ in the second last column.

The great majority of the targets were not observed before (except only 6 objects planned and observed by A. Aznar), and had no published periods by the date of our observations. During our survey, mainly Brian D. Warner targeted some objects and later published results in Minor Planet Bulletin. For comparison with our results, we include the published literature periods (PL) in the last column of our Table 2, according to the ALCDEF database[9] and upon scrutiny of the literature. Where more periods were determined before for some objects, we usually adopt the one with the most confident quality codes (U, acc. to Warner et al. [41]) and/or showing the smallest fit error.

Following our convention adopted in [36,39], we provide in the P column of Table 2 the periods in four notations, depending on the accuracy of our results.

First, with bold fonts we give in column P the *secured periods* for the best observed objects (most of them which agree well with published periods), proposed be classified with quality codes $U \sim 3$.

Second, we list with normal fonts the *candidate periods* (acronym CP) of the incompletely covered targets, possibly showing dual periods (labeled by $CP2$, typically half or double our preferred or published value) or possible secondary periods for candidate binary asteroids. We propose most of the candidate periods to be classified with quality codes $U \sim 2$.

Third, we mark in parenthesis the *tentative periods* (acronym TP) the periods of the targets insufficiently observed (most producing only a lower period limit) and some suggested periods for objects showing multiple (more than two) solutions. These tentative periods should probably correspond to quality codes $U \sim 1$ and must be regarded with caution.

Fourth, we skip assessing any periods for some *poorly observed objects* during only a short available interval, or targets observed during some nights affected by the weather. Most of these objects show flat and/or very disperse curves which cannot be trusted.

We calculated the lower limit of the ellipsoid shape ratios a/b for 46 NEAs (including 13 PHAs), assuming a simple triaxial body model with semimajor axes $a > b > c$ and the object rotation around the c axis, following the same approximations used in our past work [40]. First, we derived the light curve amplitude at zero phase angle using the expression $A(0) = A(\alpha)/(1 + m\alpha)$, where A is the amplitude and $m = 0.0225$ (the average of known slope parameters to date). The lower limits of the ellipsoid shape ratios a/b are included in Table 2.

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[5] https://www.astromatic.net/
[6] http://astrometry.net
[7] http://www.minorplanetobserver.com/MPOSoftware/MPOCanopus.htm
[8] https://vizier.u-strasbg.fr/viz-bin/VizieR
[9] http://www.alcdef.org

Five targets were observed with Mercator simultaneously in 3 bands, for which no $g - r$ colour lightcurve fit was attempted due to the very short coverage of the sessions compared with the very long period of these objects.

Table 2: 52 NEAs observed during the EURONEAR 2017-2020 lightcurve survey. Please see Section 4 for the explanation of the columns.

NEA (**PHA**)	Cls	H	Obs.nights	Telescope	V	μ	Exp	T	$H(\alpha)$	α	a/b	A	P	σ	PL
(1865) Cerberus	AP	16.7	16-17/10/17	IAO-T36	16.4-16.3	2.1-2.2	200	7	16.85	8.2-7.0	4.35	1.99	6.77	0.02	6.8044
(1981) Midas	AP	15.2	22/02-08/03/18	IAO-T36	15.4-13.7	1.0-4.2	120,30	14	16.55	36.0-38.1	1.05	0.09	**5.22**	0.01	5.20
(2059) Baboquivari	AM	16.0	12/08/19	INT	17.0	0.5	20	8	17.00	15.2	1.23	>0.3			129.43
(15745) Yuliya	AM	17.3	25-29/04/18	Mercator	18.0-17.9	0.9-0.8	120	25	19.50	35.1	1.04	0.08	P1=**3.2486**	0.0003	3.256
...	...	...	02-05/05/18	INT	17.8	0.8-0.7	120	16		35.1-35.2		0.27	P2=**15.63**	0.02	15.60
(66400) 1999 LT7	AT	19.1	26-28/06/18	Warsaw	17.2-17.3	5.9-5.8	45	11	19.88	35.1-41.6	1.06	0.11	**2.50**	0.01	
(86324) 1999 WA2	AM	15.7	21-24/09/18	INT	17.3	1.2	40,60,90	11	17.57	59.3-59.8	1.07	0.19	6.29	0.01	7.161
(89959) 2002 NT7	AP	16.5	19-21/08/18	Warsaw	16.9	3.7-3.6	60	12	16.80	22.0-24.7	1.06	0.09	CP1=2.602	0.001	5.527
...	...	...	17/09/18	Warsaw	17.7	2.0	60	5	17.62	54.3-54.5			CP2=20.05	0.01	
(96189) Pygmalion	AM	16.4	02-04/05/18	Warsaw	16.9	1.0-0.9	120	17	17.71	45.4-44.7	1.20	0.41	4.103	0.002	
(99799) 2002 LJ3	AM	18.3	26/12/18	INT	17.8	1.7	60	3	19.55	32.6-32.7	1.10	0.19	2.72	0.02	
(137062) 1998 WM	AP	16.6	11-19/11/17	Wise-T1	17.8-17.6	1.5-1.7	120,90,60	3	17.60	27.0-24.6					
(137170) 1999 HF1	AT	14.6	31/05-04/06/19	IAO-T36	16.4-16.5	1.5-1.5	180	10	16.83	58.3-57.7	1.07	0.17	CP1=2.32	0.01	2.3218
(140333) 2001 TD2	AT	19.2	16-18/09/18	Warsaw	17.6	5.7-5.2	60	11	20.21	30.4-27.1	1.04	0.07	**2.586**	0.002	
(141484) 2002 DB4	AT	16.4	07+09/02/18	SARA-S	17.0-17.1	2.1-2.0	120	7	18.95	62.5-61.9	1.08	0.20	2.989	0.001	
...	...	...	11-16/02/18	Chakana	17.1-17.3	1.9-1.8	180,240	14		61.2-60.3					
...	...	...	21/02/18	SARA-S	17.4	1.8	180	4		59.4					
(162011) Konnohmaru	AM	16.5	07+09/02/18	SARA-S	18.0	0.9	240	3	17.32	5.7-5.3	1.25	0.27	CP1=3.000	0.001	2.998
...	...	...	11-15/02/18	Chakana	18.0-18.1	0.8	240	4		4.9-5.5					
...	...	...	14-20/02/18	OSN-T90	18.1-18.4	0.8-0.7	180,250	6		5.2-7.2					
(162168) 1999 GT6	AM	17.2	31/05-04/06/18	Mercator	16.5	3.3	45	16	18.75	44.5-46.3	1.45	0.21	(TP1=15.00)	0.03	3.85
...	...	...	23-25/07/18	Warsaw	16.8	0.8	60	15	18.92	45.2-43.9					
(162882) 2001 FD58	AP	18.7	08/03/18	SARA-S	17.8	2.6	180	4	20.85	42.5	1.91	1.36	CP1=8.70	0.01	
...	...	...	09-13/03/18	Chakana	17.8-18.2	2.5-1.9	240	12		42.2-41.3					
(172034) 2001 WR1	AM	17.8	08/03/18	SARA-S	17.4	2.7	180,240	4	19.34	20.4-20.2	1.13	1.13	**8.057**	0.002	8.0475
...	...	...	09-14/03/18	Chakana	17.4-17.2	2.7-2.8	180	15		19.2-13.4					
...	...	...	17-18/03/18	BMO-T36	17.1-17.0	2.8	120	4		11.5-9.5					
(194126) 2001 SG276	AM	17.8	03/05/18	SARA-S	14.6	9.6-9.0	30	4		41.4-42.3	1.23	0.44	(TP=4.92)	0.03	5.090

Table 2 (continued from previous page)

NEA (**PHA**)	Cls	H	Obs.nights	Telescope	V	μ	Exp	T	$H(\alpha)$	α	a/b	A	P	σ	PL
...	...	...	04-06/05/18	Chakana	14.8-15.0	8.7-8.0	30	14	20.24	44.6-50.7					
...	...	...	02+04/05/18	BMO-T36	14.4-14.8	10.5-8.6	30	15	19.46	37.6-44.6					
(203015) 1999 YF3	AM	18.6	03/02/20	INT	18.3	2.6	120	4	19.70	21.9		>0.4			
(265196) 2004 BW58	AP	18.8	07+09/02/18	SARA-S	17.6	2.9	120	2	21.40	46.6-44.2	1.90	1.32	**6.4765**	0.0004	6.479
...	...	...	14-23/02/18	OSN-T90	17.7-17.8	2.5-2.1	180	16		39.4-32.8					
(293054) 2006 WP127	AP	18.4	19-26/02/20	IAO-T36	16.0-16.6	11.1-4.8	120	25	19.77	47.3-28.1	1.12	0.25	CP1=5.969	0.005	5.985
(333555) 2005 VY17	AM	17.3	11-13/01/20	INT	16.9-17.0	3.0-2.8	60	10	18.76	43.7-46.2	1.25	0.48	**5.14**	0.01	
(337084) 1998 SE36	AM	19.7	25-26/04/18	Mercator	17.8-17.9	2.0-1.9	120	11	21.05	19.9-21.4	2.17	0.95	11.84	0.01	10.85
(338347) 2002 XG4	AN	18.3	23/12/19	INT	18.5	2.0	120	4	19.27	24.6-24.8	1.04	0.07	2.40	0.04	
(349063) 2006 XA	AP	17.3	13-14/01/20	INT	17.5-17.4	2.6-2.7	120,60	10	18.65	37.7-38.1	1.04	0.09	**2.562**	0.004	2.436
(355256) 2007 KN4	AM	16.8	27/04-06/11/19	IAO-T36	17.2-16.7	0.7-1.8	180	15	17.38	8.8-45.3	1.31	0.35	**7.142**	0.001	7.14988
(374188) 2005 AD3	AM	17.4	01-05/02/20	INT	18.4	1.2	90,120	10	18.25	7.5-10.6	1.62	0.72	CP1=4.749	0.001	
(418929) 2009 DM1	AM	17.0	25/09/18	INT	16.3	1.5	30	3	17.81	23.2-23.3		>0.05	(TP>12)		4.590
(444584) 2006 UK	AP	20.2	05-09/11/17	Wise-T1	16.4-15.7	2.7-5.8	120,70,20	5	20.65	16.1-22.4	1.92	0.21	5.70	0.01	5.721
...	...	...	07+09/11/17	IAO-T36	16.1-15.6	3.8-5.7	60,20	12		18.5-23.1					
(448818) 2011 UU20	AM	17.9	03-04/02/20	INT	18.3-18.2	1.5-1.7	120	17	19.35	53.3		0.29	(TP1=4.37)	0.01	
(453778) 2011 JK	AM	18.5	07-10/06/19	IAO-T36	16.5-16.6	5.0-4.6	240	11	20.55	52.7-50.6	1.06	0.14	(TP1=2.58)	0.01	2.4567
(455736) 2005 HC3	AM	17.8	13/06/19	INT	17.7	3.1	60	6	18.65	17.8-17.5	1.15	0.11	(TP1=2.45)	0.02	14.40
(467309) 1996 AW1	AP	19.9	31/05-04/06/18	Mercator	17.6-17.2	1.8-2.6	120	19	21.05	19.2-22.2	1.22		**10.799**	0.002	10.773
(496005) 2007 XJ16	AM	19.1	31/10-03/11/17	Wise-T1	17.5-18.1	2.5-1.7	120	10	20.23	30.6-25.0	1.50	0.69	5.98	0.01	
(512245) 2016 AU8	AT	19.9	27/12/18	INT	17.7	2.8-2.9	60	10	21.16	40.4-39.9	1.20	0.29	**4.44**	0.01	4.516
(523587) 1999 VQ11	AM	17.5	25/09/18	INT	18.0	2.5	120	3	19.30	61.4			(TP>12)		32.21
(523611) 2005 UY5	AM	18.6	23-25/07/18	Warsaw	17.9	0.6-0.5	120	11	19.12	21.3-22.2	1.07	0.19	(TP1=5.56)	0.02	
(523630) 2009 OG	AP	16.2	26-28/06/18	Warsaw	17.6	3.5-4.0	90	11	17.45	53.7-55.9	1.07	0.24	**2.594**	0.001	
(523824) 2016 RO1	AM	19.6	28/12/18	INT	17.6	5.3	30	2	21.35	63.3	1.45	0.90	CP1=9.334	0.003	
...	...	...	01-03/01/19	TAR3	17.6-17.7	5.3-4.9	180	11		63.4					
(533541) 2014 JU54	AM	19.9	28-30/12/18	INT	17.3-17.6	7.5-6.1	30	11	21.77	51.7-55.3		0.44	CP1=10.24	0.03	

Table 2 (continued from previous page)

NEA (**PHA**)	Cls	H	Obs.nights	Telescope	V	μ	Exp	T	$H(\alpha)$	α	a/b	A	P	σ	PL
1999 AF4	AM	18.5	22-24/12/17	IAO-T36	16.0-15.8	4.5-5.0	120	16	20.07	43.2-41.8	1.11	0.09	CP1=3.11	0.02	3.123
2000 BO28	AP	19.7	02/03/20	INT	17.7	2.9	90	4	20.62	18.6	1.07	0.10	CP1=2.9	0.1	3.2392
2005 RB	AM	20.3	16/09/18	Warsaw	17.2	5.2	120	1		5.4-5.7	2.38	1.06	CP=8.260	0.002	8.2780
...	...	...	21-25/09/18	INT	17.5-17.7	5.1-4.6	40	16	21.32	14.5-21.6					
2008 LW16	AP	19.9	21/06/19	INT	18.1	5.3	30	4	21.29	35.1-34.8	1.32	>0.3	(TP=12)	1	
2009 SK104	AM	19.4	27-29/04/18	Mercator	17.6	1.6	120	8	21.05	33.3-35.6	1.14	0.67	CP=34.57	0.03	34.66
...	...	...	02-04/05/18	Warsaw	17.5-17.4	1.7-1.8	120	13	20.53	38.7-40.9					
2011 LH	AM	19.7	14/06/19	INT	17.9	6.6	20	6	20.43	11.3-10.9	1.08	>0.2	(TP=16)	2	
2011 UA	AM	18.6	21-24/09/18	INT	16.6-16.8	1.3-1.1	60	9	19.80	18.3-16.4	1.03	>0.63	(TP1=30.0)	0.2	0.316391
2015 JD1	AP	25.5	09/11/19	IAO-T36	15.08	40.1	30	5	22.39	12.97	1.41	0.82	CP=5.2	0.1	5 .212
2017 SO17	AM	18.8	11-15/11/17	IAO-T36	16.3-16.2	6.2-6.7	60	13	19.83	27.5-26.7	1.10	0.13	**3.811**	0.03	
2017 YH1	AP	21.2	25-29/12/17	IAO-T36	14.4-17.5	2.3-0.9	150	10	22.95	34.0-33.6	1.39	0.56	**4.820**	0.002	
2017 YN3	AM	19.2	13-14/01/18	IAO-T36	15.2	25.2	30	3	20.30	18.4-26.1	1.10	0.16	CP=0.444	0.001	0.361
2018 CU1	AP	20.9	21-22/02/18	OSN-T90	17.8	9.7-8.7	150	1		25.0-20.9	1.09	0.13	(TP=3.2)	0.1	
...	...	...	04/03/18	INT	18.6	3.8	90	5	22.00	11.7-11.9					

4.1 Secure Periods

(1981) Midas is a large PHA of 2.0 km which was observed with the IAO-T36 telescope during 4 nights in Feb-Mar 2018 (about 14 hours total). Its low amplitude curve ($Amax = 0.09$ mag) could be fit by the secure period $P = 5.22 \pm 0.01$ (Figure 1), matching results of other authors including Mottola et al [19] ($P = 5.220$ h), Wisniewski et al [54] ($P = 5.22$) and Franco et al [13] ($P = 5.20 \pm 0.01$) who observed in the same period with our run.

(15745) Yuliya is a large Amor NEA of about 1.0 km diameter (assuming a standard albedo 0.20). Observations started in late April 2018 with Mercator (5 nights), then continued in early May with the INT (4 nigths), adding in total about 41 hours of data. In a preliminary analysis led by A. Aznar which involved P. Pravec, we discovered that this asteroid is binary, publishing the primary period $P = 3.2486 \pm 0.0003$ ($Amax = 0.10$ mag) and an orbital period of the secondary of $Porb = 15.63 \pm 0.02$ h [5]. Based on 10 nights observations in early May 2018, B. Warner [45] find a similar result ($P = 3.256 \pm 0.002$ h, Porb=15.60 h, $U = 2-$). Using data collected during 8 nights in June 2018 using a 0.35 m telescope at Sopot Astronomical Observatory and the custom ALC period analysis software, Benishek and Pravec [7] re-determined the period of the primary $P = 3.2495 \pm 0.0002$ h (nearly identical to our result), and the orbital period of the secondary $Porb = 11.735 \pm 0.003$ h (4 h lower than our result). Adding all 9 nights Mercator and INT data, we can secure now the primary period $P1 = 3.2486 \pm 0.0003$ (Figure 1) and the orbital period of the secondary $P2 = 15.63 \pm 0.02$ h ($Amax = 0.27$ mag), which are very close to Warner's findings, included in the last column of Table 2. Based on the Mercator data taken simultaneously in 3 filters of this binary system, we derive a colour $g - r = 0.64 \pm 0.06$, calculated as the average of the colours for the five nights derived as the median colours measured nightly on all individual images.

(66400) 1999 LT7 is a NEA Aten of 0.4 km which was observed during 3 nights in Jun 2019 (about 11 hours total) using the Warsaw telescope. Its relatively flat curve (maximum amplitude $A = 0.10$ mag) can be fit with the secure period $P = 2.50 \pm 0.01$ (Figure 1) using order 2. This object does not have any other published period, but has collected other physical data.

(99799) 2002 LJ3 is a 0.6 km Amor NEA which was observed with the INT during one available night in Dec 2018 for only 3.5 hours. Its lightcurve could be fit (albeit with a small overlap) using orders 5-8 with the candidate period $P = 2.72 \pm 0.02$ hours (Figure 2). No other authors published any period for this object which nevertheless has published other physical data.

(140333) 2001 TD2 is an Aten NEA 0.4 km which was observed during 3 nights in Sep 2018 (11 hours total) with the Warsaw telescope. We derived the secure period $P = 2.586 \pm 0.002$ h with a very shallow amplitude $Amax = 0.07$ mag, using orders 2-8 (adopting order 4). There is no other published period for this object, except for some physical data.

(172034) 2001 WR1 is an Amor NEA of 0.6 km diameter. Observations started during March 2018 (23 hours in total) using SARA-S (one night), then Chakana telescope (5 nights) and finally by the EURONEAR collaborator J. Oey from Australia (during 2 nights). The whole dataset could be fit with the secure period $P = 8.057 \pm 0.002$ h (with very large amplitude $Amax = 1.13$ mag and using order 8). This fit matches the solution of B. Warner [44] ($P = 8.0475 \pm 0.0003$, $Amax = 0.95$, order=8, $U = 3+$) who observed the object during 6 nights in a similar period.

(265196) 2004 BW58 is an Apollo PHA of 0.4 km diameter, observed in Feb 2018 with the SARA-S (one night), then OSN-T90 (6 nights) for about 18 hours in total. Based on its lightcurve (Figure 1), we derived a secured period $P = 6.4759 \pm 0.0004$h (order=10 with a very deep $Amax = 1.38$ mag). This target was also observed by B. Warner [44] during 3 nights in the same interval, who derived the same period ($P = 6.479 \pm 0.001$, order=6, $Amax = 1.22$, $U = 3$).

(333555) 2005 VY17 is a large Amor NEA of about 1.0 km (assuming a standard albedo 0.2) which was observed during 3 consecutive nights in Jan 2020 using the INT (total 10 hours). Its lightcurve resulted in a secured period $P = 5.13 \pm 0.01$ ($Amax = 0.46$ mag, order=6, data binning 2) presented in Figure 1. There is no other physical data about this object in the literature.

(349063) 2006 XA is a large Apollo NEA of about 1.0 km (assuming an albedo of 0.2) observed in Jan 2020 during 2 consecutive nights with the INT (total 10 hours). We could fit the secure period $P = 2.562 \pm 0.004$ h ($Amax = 0.09$ mag, order=4, binning 2) included in Figure 1. This is confirmed by B. Warner [52] who observed the target during 4 nights in Jun 2020 obtaining a very close result ($P = 2.436 \pm 0.002$, $Amax = 0.23$ mag, order 4, classified as $U = 2+$).

(355256) 2007 KN4 is a large 1.1 km Amor NEA (assuming albedo 0.2) targeted with the IAO-T36 telescope during 8 nights (15 hours in total) spanning a very long interval between May-Jul 2019. We propose the secure period $P = 7.142 \pm 0.001$ ($Amax = 0.31$ mag, binning 2, order 2) with the plot included in Figure 1. This confirms three other results, including Pal et al. [21] based on TESS data ($P = 7.14988 \pm 0.00005$ h, $Amax = 0.37$, $U = 2$).

(444584) 2006 UK is an Apollo PHA of 0.3 km (assuming albedo 0.2) observed in Nov 2017 using WISE (3 nights) and the IAO-T36 telescope (2 nights), for a total of 17 hours. We derived a secure period $P = 5.70 \pm 0.01$ h ($Amax = 0.21$ mag, order 2, binning 2 - Figure 1) which matches the result of Pravec 2019 ($P = 5.721 \pm 0.001$, $Amax = 0.24$, U=3, web source) based on data collected during 6 nights in Oct 2017.

(467309) 1996 AW1 is an Apollo PHA of about 0.15 km, observed during 5 nights in May-June 2018 with the Mercator telescope (19 hours total time). We derived a secure period $P = 10.799 \pm 0.002$ h ($Amax = 1.12$ mag, order=6, RMS=0.039 mag) using the r-band data, which matches the g-band fit ($P = 10.789 \pm 0.006$ h, $Amax = 1.16$ mag, order=6 RMS=0.047) - both included in Figure 1. The object was also covered by B. Warner during 4 nights one week after our run [45], who derived the same period ($P = 10.773 \pm 0.004$ h, $Amax = 1.25$ mag, order=10). Averaging the colours of the first three longest sessions, we derive its colour $g - r = 0.45 \pm 0.04$ mag.

(512245) 2016 AU8 is an Aten NEA of 0.3 km observed with the INT during only one night in Dec 2018 (10 hours). We derived a secure period $P = 4.44 \pm 0.01$ h ($Amax = 0.29$ mag using order 6 - Figure 1), matching three other results (data from 2018, 2019 and 2020) which include B. Warner [49] ($P = 4.516 \pm 0.002$ h, $Amax = 0.31$ mag, order=4, uncertainty U=3) who observed the target just one week following our run.

(523630) 2009 OG is a large Apollo PHA of about 1.7 km (assuming 0.2 albedo) which was observed during 3 nights in Sep 2018 using the Warsaw telescope (11 hours total). We derived the secure period $P = 2.594 \pm 0.001$ ($Amax = 0.24$ mag, order=4, Figure 1), which is the first result for this target.

2017 SO17 is an Amor NEA measuring about 0.5 km (assuming albedo 0.2) observed during 3 nights in Nov 2017 with the IAO-T36 telescope for 13 hours total time. We derived a secure period $P = 3.811 \pm 0.003$ h ($Amax = 0.13$ mag, orders=2-8, binning=2, Figure 1) which is the only solution in the literature.

2017 YH1 is an Apollo PHA measuring about 0.2 km (assuming albedo 0.2) observed during 4 nights in Dec 2017 with the IAO-T36 telescope (10 hours total). We could secure a period $P = 4.820 \pm 0.002$ h ($Amax = 0.56$ mag, orders=2-8, see Figure 1) which can't be checked versus any other result.

4.2 Candidate Periods

(1865) Cerberus is an Apollo NEA of 1.2 km observed during 2 nights in Oct 2017 (7 hours total) using the IAO-T36 telescope, but about half of the curve was sparsely populated by data. Its candidate period gives $P = 6.77 \pm 0.02$h (Figure 2), which matches previous results of many authors, including Warner and Stephens [46] ($P = 6.8044 \pm 0.0006$h, observed during six nights), Durech et al [12] ($P = 6.80328 \pm 0.00001$ h) and Hanus et al [14] ($P = 6.803286 \pm 0.000005$ h) which should be adopted.

(86324) 1999 WA2 is a large 2.1 km Amor NEA which was observed for 4 nights in Sep 2018 with the INT (11 hours total). No classic order 2 curve can be fitted, but a candidate period $CP1 = 6.29 \pm 0.01$ h could be derived using orders between 4-10. Based on the period spectrum plot (Figure 2), another longer period could be possible ($CP2 = 8.38 \pm 0.01$), but this is incompletely covered. Based on 11 night coverage, Warner and Stephens [47] derived a different period ($P = 7.161 \pm 0.003$, order 4), but their fit seems quite noisy and our data can't reproduce it.

(89959) 2002 NT7 is a large Apollo PHA between 1.1-1.9 km diameter, targeted with the Warsaw telescope during 4 nights in August 2018 (first 3 consecutive nights), then September 2018 (one more night, 3 weeks later), adding a total of 17 hours. The first 3 nights suggest a candidate period $CP3 = 3.89 \pm 0.01$ h ($Amax = 0.11$ mag, orders=3-6), the fourth night another period $CP4 = 2.63 \pm 0.02$ h ($Amax = 0.11$ mag, orders=2-6), while all 4 nights seem to converge to $CP5 = 3.887 \pm 0.001$ h ($Amax = 0.11$ mag, orders=3-6), but all these solutions show some scatter for some parts of the data. Investigating this discrepancy, we considered binary analysis which seems to be consistent with a binary object, with the candidate period of the primary $TP1 = 2.602 \pm 0.001$ h ($Amax = 0.09$ mag, order 5) and the orbital period of the secondary $CP2 = 20.05 \pm 0.01$ h. We include all these fits in Figure 2. Warner and Stephens [50] observed this target during 4 nights in January 2019 at a large solar phase angle (63 deg), proposing a longer period ($P = 5.527 \pm 0.003$ h, $Amax = 0.25$ mag, order 4, U=3-). Using TESS relatively scattered data from 10 nights, Pal et al. [21] proposed another longer solution ($P = 10.0377 \pm 0.0005$ h, $Amax = 0.11$ mag, classified as U=2 in ALCDEF database). None of these authors suggested any binarity, and we believe a dedicated campaign should be called in the future, for an indepth investigation of this PHA.

(96189) Pygmalion is a large 3.6 km Amor NEA which was observed during 2 nights in May 2018 with the Warsaw telescope (17 hours total). We derived the candidate period $CP = 4.103 \pm 0.002$ h ($Amax = 0.41$ mag) using orders=2-6, which was apparently covered almost completely (Figure 2). There is no other period published in the literature.

(137170) 1999 HF1 is a large 4.4 km Aten NEA which was observed during four nights (10 hours total) with the small IAO-T36 telescope. This relatively bright object was found to be binary by Pravec [25,26] and Marchis [18], being studied by many other authors which include B. Warner in 2016 [42] ($P = 2.3218 + / - 0.0002$) who could not confirm any binarity feature. We could reproduce their findings, fitting the relatively noisy candidate period of the primary $CP1 = 2.32 \pm 0.01$ (Figure 2).

(141484) 2002 DB4 is a large 1.0-1.2 km Aten NEA targeted in Feb 2018 during 5 nights using the Chakana telescope, then 2 more nights with SARA-S (about 25 hours in total). We propose the candidate period $CP = 2.989 \pm 0.001$ h using orders 6 or 3 (Figure 2). No other period was published by other authors, nevertheless the object has other published physical data, including few albedo.

(162011) Konnohmaru is a large Amor NEA of 1.4 km. Observations observed in Feb 2018, first with the SARA-S telescope (2 nights), then with Chakana telescope (3 nights), and finally with the OSN-T90 telescope (2 nights), adding together 13 hours of data. Two candidate periods could be fit using slightly different offsets between sessions, namely $CP1 = 3.000 \pm 0.002$ ($Amax = 0.26$ mag, order 5) and $CP2 = 2.660 \pm 0.001$ ($Amax = 0.23$ mag, order 5). In Figure 3 we give both plots and period spectra; the first is preferred, matching the result of B. Warner [44] ($P = 2.998 \pm 0.002$ h, $Amax = 0.20$ mag, order=4, $U = 3-$) based on data collected during 3 nights.

(162882) 2001 FD58 is an Apollo PHA of 0.6 km. Observations started in early March using SARA-S (one night), then continued during with the Chakana telescope (4 nights), adding together 16 hours. The period spectrum plot suggest two incompletely covered periods, namely $CP1 = 8.70 \pm 0.01$ h ($Amax = 1.36$ mag, orders=2-3, rms=0.148 - preferred by us) and $CP2 = 12.89 \pm 0.02$ h ($Amax = 1.43$ mag, orders=2-3, rms=0.152) - see Figure 2. There is no other published period for this object which has one albedo determination.

(293054) 2006 WP127 is an Apollo NEA of about 0.6 km (assuming standard albedo 0.2) observed during 6 nights in Jul 2019 with the IAO-T36 telescope (25 hours total). The individual measurements show lots of scatter due to the small size of the telescope, but binning every 3 points concluded with a candidate period $CP1 = 5.969 \pm 0.004$ ($Amax = 0.22$ mag, order=2, RMS=0.083 mag). Another extremely similar fit results in $CP2 = 5.309 \pm 0.005$ h ($Amax = 0.21$ mag, order=2, RMS=0.085 mag). We include these two fits and the period spectrum in Figure 2 and we prefer $CP1$ as solution. This target was observed twice by B. Warner, first during 7 nights in 2015 [43] matching our CP2 result ($P = 5.311 \pm 0.002$ h, U=2+), and second during 3 nights in July 2019 (same interval with us) [51] matching our CP1 finding ($P = 5.985 \pm 0.002$ h, $Amax = 0.36$ mag, U=3).

(337084) 1998 SE36 in an Amor NEA of about 0.3 km (assuming albedo 0.2) which was observed during 2 consecutive nights in April 2018 in two bands using Mercator telescope (11 hours total). Assuming a bimodal solution based on the symetrical monomodal fit, both r and g bands conclude with a candidate period $CP1 = 11.84 \pm 0.01$ h ($Amax = 0.98$ mag, order=2, binning 2, included in Figure 2). The period spectrum plot shows two other very close minima (labeled in Figure 2), suggesting other possible candidate periods (coinciding in both bands), namely $CP2 = 9.55 \pm 0.02$ h ($Amax = 0.97$ mag, order=2) and $CP3 = 7.90 \pm 0.02$ h ($Amax = 1.02$, orders 2-4, incompletely covered) which we include in Figure 2, but we discard both. Our preferred candidate period $CP1$ is confirmed by B. Warner [45] ($P = 10.85 \pm 0.02$, $Amax = 0.96$ mag, order 2), and Pravec ($P = 11.855 \pm 0.002$, $Amax = 1.22$ mag, order 8, web source), both observing the target in the same period with our run. Averaging the Mercator colours from the two nights, we derive $g - r = 0.56 \pm 0.20$ mag for this NEA.

(338347) 2002 XG4 is a large Amor NEA (1.4-1.9 km diameter, based on two very low albedo determinations) observed during one available night with the INT (4 hours total). Albeit some scatter during the first half hour and the very low amplitude (Figure 2), its curve could be fit with the candidate period $CP = 2.40 \pm 0.04$ h ($Amax = 0.07$ mag, orders 2-4). There is no other published solution to compare.

(374188) 2005 AD3 is a large 1.1 km Amor NEA targeted in Feb 2020 during 3 nights with the INT (9 hours total). Few minima appear visible on the period spectrum included in Figure 2, from which we favor the deepest one corresponding to the candidate period $CP1 = 4.749 \pm 0.001$ h ($Amax = 0.72$ mag, orders 4,6). Apparently no other author observed this target which has one albedo determination.

(496005) 2007 XJ16 is an Amor critical-listed PHA of about 0.4 km which was observed during 3 nights in Oct-Nov 2017 with the WISE 1-m telescope (10 hours total). We propose the candidate period $P = 5.98 \pm 0.01$ h ($Amax = 0.69$ mag, orders 2-3) plotted in Figure 2. Apparently, nobody else has observed this target yet, which has one albedo determination.

(523824) 2016 RO1 is an Amor NEA of about 0.3 km (assuming albedo 0.2) which was started during one night in Dec 2018 with the INT, then completed with the TAR3 during 3 nights around the new year 2019 (13 hours total). After binning to smooth TAR3 data, we derive a candidate period $CP1 = 9.334 \pm 0.003$ h ($Amax = 0.90$ mag, orders=2,4-8, rms=0.049 mag) which is preferred versus another period $CP2 = 7.777 \pm 0.003$ h (not completed, $Amax = 0.90$ mag, orders=4-8, rms=0.072 mag). We include these fits and period spectrum in Figure 2. There is no other published period or other physical data for this object.

(533541) 2014 JU54 is an Amor critical-listed NEA of about 0.3 km (assuming albedo 0.2) observed during 3 nights in Dec 2018 with the INT (11 hours total). Two odd jumps (way out of error bars) appear in the third night JD plot (see Figure 2) which neither the weather, nor any stars or galaxies in the path can explain, including about 2-3 sudden V-shaped drops in the last part of the data (red symbols), typically suggesting eclipses in binary objects. Two candidate mono-modal solutions could be fit (because both fits miss complete coverage), namely $CP1 = 10.24 \pm 0.03$ h ($Amax = 0.44$ mag, based on the first 2 nights) preferred by us, and $CP2 = 15.17 \pm 0.02$ h ($Amax = 0.51$ mag, based on all 3 nights) after deleting many jumping points (32 in total, 19 from the first and 23 from the second portion of the night). There is no other published result or physical data for this slow rotator object, which needs a dedicated campaign (preferably from multiple stations) to nail down its long period and our binarity supposition.

1999 AF4 is an Amor NEA about 0.6 km (assuming albedo 0.2) which was observed during 2 nights in Dec 2017 using the IAO-T36 30-cm telescope (16 hours total). We derive the candidate period $CP1 = 3.11 \pm 0.02$ h ($Amax = 0.09$ mag, orders 2-6, rms=0.031 mag) which is very close to the half of another possible fit based on incomplete coverage ($CP2 = 6.20 \pm 0.02$ h, $Amax = 0.12$ mag, orders 3-6, rms=0.030 mag). We include the CP1 plot and period spectrum in Figure 2. Two other observers found the same results based on data taken one month after our run, from which we mention B. Warner ($P = 3.123 \pm 0.002$ h, $Amax = 0.11$, order=4, U=3-) [44].

2000 BO28 is an Apollo PHA of about 0.3 km diameter (assuming albedo 0.2) which was targeted during only one available night in Mar 2020 with the INT telescope (4 hours). We found two candidate periods, namely the preferred solution $CP1 = 2.9 \pm 0.1$ h ($Amax = 0.10$ mag, orders 2,3,5,6; rms=0.037 mag) and another value matching the whole coverage ($CP2 = 3.9 \pm 0.1$ h, $Amax = 0.11$ mag, order=4, rms=0.036 mag). We include these fits and the period spectrum in Figure 2. Using the 1.5 m Danish telescope from La Silla during 6 nights in a similar period, Pravec et al. (web source) found a period slightly longer than our CP1 value ($P = 3.2392 \pm 0.0002$ h, $Amax = 0.08$ mag, order=8) but their fit seems quite uncertain (U=2-).

2005 RB is an Amor NEA of about 0.3 km (assuming an albedo 0.2). Observations started in Sep 2018 using the Warsaw telescope (only half hour during one night), then continued with the INT during 4 more nights (17 hours total). Droping the Warsaw data (which seems tilted with respect to the other data, possibly due to the parallax effect), we propose the candidate period $CP = 8.260 \pm 0.002$ h ($Amax = 1.06$ mag, orders=2-8, binning 2) although the coverage is incomplete (Figure 2). Three other authors derived very close periods based on observations in the same interval, from whom we mention Pravec 2018 (web source; $P = 8.2780 \pm 0.0005$ h, $Amax = 1.13$ mag, U=3).

2009 SK104 is an Amor NEA of about 0.4 km (assuming an albedo 0.2). Observatuins begun in April 2018 during 3 nights using Mercator, being continued with Warsaw during other 3 nights (for about 21 hours in total). We derived 3 very similar fits in each of the 3 observed bands (Figure 2), and taking into account r and I data we suggest the candidate period $CP = 34.57 \pm 0.03$ h ($Amax = 0.67$ mag, order=4, binning 2) included in Figure 2. This target was observed in the same period by Pravec et al. (2019 web source) who derived a fit very close to our findings based on 13 nights data ($P = 34.66 \pm 0.04$ h, $Amax = 0.28$ mag, order=2), but their data seems quite noisy around the fit (U=2). Based on TESS data, Pal et al. [21] derived a different period ($P = 24.1574 \pm 0.0005$, $Amax = 0.84$ mag, U=2) which can't be reproduced in our period spectrum (Figure 2). Averaging the Mercator colours from the three nights, we derive $g - r = 0.48 \pm 0.07$ mag. Based on La Silla Danish 1.5m observations in two bands, Pravec derived $V - R = 0.422 \pm 0.013$ mag.

2015 JD1 is an Apollo PHA of about 0,2 km (assuming 0.2 albedo) which was observed during one night (5 hours) in Nov 2018 with the IAO-T36 telescope. We propose the candidate period $CP = 5.2 \pm 0.1$ h ($Amax = 0.82$ mag, order=4, binning 2) which matches the solution of Pravec et al. ($P = 5.2057 \pm 0.0004$ h, $Amax = 0.58$ mag, U=3-, acc to web source, observed one week before during 5 nights) and Warner and Stephens [53] ($P = 5.212 \pm 0.218$ h,

$Amax = 0.71$ mag, U=3, derived from 3 nights).

2017 YN3 is an Amor NEA of 0.5 km which was observed during 2 nights in Jan 2018 with the IAO-T36 telescope (only 3 hours total). We propose the candidate period $CP = 0.444 \pm 0.001$ h ($Amax = 0.16$ mag, orders=2-5). Labrevoir and Behrend (web source) observed this target one week after us, deriving a provisory period quite close to our solution ($P = 0.361 \pm 0.006$ h, $Amax = 0.21$ mag, web source), but their data look quite dispersed (U=1).

4.3 Tentative Periods

(162168) 1999 GT6 is a large Amor NEA of 1.1 km (assuming standard albedo of 0.2). It was started early June 2018 using Mercator (during 5 nights), being continued with Warsaw telescope late July 2018 (during 3 nights), adding together 31 hours of data. We attempted independent fits in all 3 bands (Figure 3), proposing a tentative period $TP1 = 15.00 \pm 0.03$ h ($Amax = 0.21$ mag, order=8) obtained by averaging the values in the 3 bands, namely r, g (Mercator) and I (Warsaw). Another tentative solution $TP2 \sim 18.0$ could be observed in all spectrum plots (Figure 3). Using quite sparse data observed during 7 nights in the same period with our Mercator run, B. Warner [45] derived a period much shorter than our result ($P = 3.85 \pm 0.01$ h, $Amax = 0.15$ mag, order=4, U=2) which can not be reprodused by any of our nights. Averaging the Mercator colours of the 3 nights, we obtain $g - r = 0.53 \pm 0.05$.

(194126) 2001 SG276 is an Amor NEA of about 0.8 km (assuming an albedo 0.2) which was observed in May 2018 using SARA-S telescope (one night) then the next night with Chakana, adding together 18 hours of data. Using only the last three nights observed with Chakana, we can fit a tentative period $TP1 = 4.85 \pm 0.02$ h ($Amax = 0.23$ mag, order 8). This is confirmed by SARA-S $TP2 = 4.13 \pm 0.06$ h incompletely covered, which curiously shows almost double amplitude ($Amax = 0.43$ mag, order 8) which could suggest a binary system. Despite some imperfect overlap (due to the large amplitude of SARA-S), the two datasets can be fit together in a similar period $TP3 = 4.74 \pm 0.01$ h ($Amax = 0.38$ mag, order 8). We include all these fits in Figure 3. Independently, the object was observed by J. Oey during six nights (Apr-May 2018). Two of these nights (4-5 May 2018) lead to similar fits, namely for the first night (n1) we find the tentative period $TP4 = 4.935 \pm 0.024$ h ($Amax = 0.08$ mag, order 8), while for the second night (n2) we find $TP5 = 5.099 \pm 0.006$ h ($Amax = 0.21$ mag, order 8), both included in Figure 3. Combining these two nights with other nights of Oey's larger dataset, result in larger residuals which could also suggest a binary system. Averaging the values of TP1, TP2, TP4 and TP5, and taking into account the above observations regarding the impossibility to fit multiple nights, we suggest a binary system with a tentative period of the primary $TP = 4.92 \pm 0.03$, which we include in Table 2. This target was also observed during five nights by B. Warner [44] who suggested a period very close to our results ($P = 5.090 \pm 0.004$ h, $Amax = 0.22$ mag, order 4, $U = 2+$) but did not suspect any binarity. This NEA was the target of the Arecibo radar in Apr 2018.

(448818) 2011 UU20 is a relatively large Amor NEA of about 0.8 km (assuming 0.2 albedo). It was observed during 2 nights in Feb 2020 with the INT (about 17 hours total). The target was very faint and the Moon was bright, and the second night resulted very scaterred and had to be dropped. Using the first night alone (about 7 hours), two solutions appear possible, from which we prefer the tentative period $TP1 = 4.37 \pm 0.01$ h ($Amax = 0.29$ mag, orders 3-5, $RMS = 0.060$) and we discard $TP2 = 5.25 \pm 0.02$ h ($Amax = 0.27$ mag, order=2, $RMS = 0.065$). We include these fits along with the period spectrum in Figure 3. There is no other lightcurve in the literature to compare with.

(453778) 2011 JK is an Amor PHA of 0.5 km which was observed in June 2019 during 3 nights with the small IAO-T36 telescope (11 hours total). We suggest a tentative period $TP1 = 2.58 \pm 0.01$ h ($Amax = 0.15$ mag, order=3) but the data looks quite scattered above error bars along the fit, especially due to first night set (Figure 4). This result agrees with Skiff et al. [27] who used a 1.1 m telescope during two nights just a few days before our run, obtaining a very good fit ($P = 2.4567 \pm 0.0008$ h, $Amax = 0.12$, order=7, $U = 3$). Warner & Stephens also targeted the same object about 3 weeks before our run during 4 nights, but their data has larger error bars [48], obtaining a similar result ($P = 2.4580 \pm 0.0004$ h, $Amax = 0.33$ mag, order=4, $U = 2+$). Based on archival TESS data, Pal et al. [21] derived a different period ($P = 1.96547 \pm 0.00005$ h, $Amax = 0.18$ mag, $U = 2$) which do not confirm other results and can't be reproduced based on our OAI dataset or period spectrum (Figure 4).

(455736) 2005 HC3 is an Amor NEA of about 0.8 km (assuming 0.2 albedo) which was observed during only one available night in June 2019 with the INT for 6 hours. We derive a tentative period $TP1 = 2.45 \pm 0.03$ hours ($Amax = 0.10$ mag, binning=2 and orders=2-4) - see Figure 3. The target was observed by Warner and Stephens during 10 nights in the same period [48] who derived a different solution ($P = 14.4 \pm 0.02$ h, $Amax = 0.34$ mag, order=4, classified with uncertainty U=3-). Maybe the target is a tumbling asteroid and we could derive its primary period, more data would be needed to sort this supposition.

(523611) 2005 UY5 is an Amor NEA of about 0.6 km (assuming an albedo of 0.2) which was observed during 3 nights in July 2018 with the Warsaw telescope (about 11 hours total). Three solutions appear possible after discarding the third night (hardly affected by weather) and binning 2 times the data, namely: $TP1 = 5.56 \pm 0.02$ h ($Amax = 0.19$ mag, orders=7,2, rms=0.037 mag) - chosen as our tentative period, $TP2 = 3.18 \pm 0.01$ h ($Amax = 0.15$ mag, orders=4,5, rms=0.041 mag) and $TP3 = 2.54 \pm 0.01$ h ($Amax = 0.12$ mag, order=3, rms=0.046 mag), all included in Figure 3. Apparently no other author observed this faint object.

2008 LW16 is an Apollo PHA of about 0.3 km (assuming an albedo 0.2) which was observed during one available INT night in June 2019 for about 4 hours. The period seems to be longer than the coverage, but we can suggest the tentative period $TP \sim 12 \pm 1$ hour ($Amax > 0.3$ mag, order 2, binning 2), assuming a bimodal model (Figure 3). This object was not observed by anybody else.

2011 LH is an Amor NEA of about 0.3 km (assuming albedo 0.2) which was observed during one available INT night in June 2019 (6 hours). Although the coverage is far from complete, assuming a bi-modal model we could suggest a tentative period $TP \sim 16 \pm 2$ h ($Amax > 0.22$, order=2, binning 2 - see Figure 3). There is no other solution published yet for this object.

2011 UA is an Amor NEA of about 0.6 km (assuming 0.2 albedo) targeted during 4 nights in Sep 2018 with the INT (about 9 hours total). Each session shows dispersion below ~ 0.05 mag around some relatively flat night trends, but all nights appear to show a clear descent which suggests a very slow rotation (Figure 3). If no offset is applied, then all nights will suggest a long tentative period $TP1 = 30.0 \pm 0.2$ mag ($Amax > 0.63$ mag, orders=2-4 - Figure 3). The alignment of all nights needs large unusual offsets to apply, namely up to 0.58 mag (much larger than uncertainties of the 2-5 SDSS stars used as references in each field). Forcing such arbitrary night alignment only increases the scatter around the apparently flat background, resulting in very uncertain fits, which we can reject. Each night fit (covering 2-3 hours of data) using order 2 gives different possible solutions of very small amplitudes, namely $TP2 = 1.07 \pm 0.04$ h for night 1 ($Amax = 0.02$ mag), $TP3 = 0.35 \pm 0.01$ h for night 2 ($Amax = 0.01$ mag), $TP4 = 0.53 \pm 0.01$ h for night 3 ($Amax = 0.04$ mag), and $TP5 = 1.22 \pm 0.06$ h for night 4 having poorest data ($Amax = 0.05$ mag) - all included in Figure 3. Four weeks before us, Warner and Stephens [47] observed this object during four nights, confirming the large scatter (0.2-0.3 mag) around some relatively flat trends observed during each night. They suggest tumbling status and make an extensive analysis of three possible fits from which they prefer the bi-modal solution $P = 0.316391 \pm 0.000007$ h ($Amax = 0.13$ mag, U=3-), which comes very close to our $TP3$ tentative period derived from the INT second night. Nevertheless, this period can't be forced to any other INT nights, and playing the fitting order just adds more uncertainty of any other better solution. Clearly this is a strange NEA which appears to be located in a strange position of the period-diameter plot [47] and needs a dedicated campaign, preferably from multiple stations to sample potential longer periods. Coupling the INT with the results of Warner and Stephens, we suggest a tumbling object with a short period ~ 0.3 h and a long tentative period around ~ 30 h.

2018 CU1 is an Apollo NEA of about 0.2 km (assuming albedo 0.2). It was started with the OSN in Feb 2018 (2 very poor nights), then continued with the INT in March 2018 (one night) for a total of 6 hours. Droping the OSN data (due to poor weather and large error bars), we propose the tentative period $TP = 3.2 \pm 0.2$ h ($Amax = 0.13$ mag, orders=2-4 - Figure 3). There is no other published solution for this NEA.

4.4 Poorly Observed Objects

(2059) Baboquivari is a large 1.8 km Amor NEA which was observed with the INT for 8 hours during only one available bright night in Aug 2019. Its curve is relatively flat, showing about six dips (Figure 4) which confirm the findings of Warner and Stephens [46] who suggested a very wide binary or a tumbler, based on their binary analysis (extended data collected during 23 nights) which resulted in very slow rotation of the primary ($P = 129.47 \pm 0.04$ h) and a secondary period (19.199 h).

(137062) 1998 WM is a large 1.3 km Apollo NEA targeted during 4 nights in Nov 2017 with the WISE 1-m telescope. All nights show jumping data with amplitudes between 0.2 and 0.7 mag in the raw plot (Figure 4). Neither a fast spin model, nor our previous low amplitude candidate period ($P = 2.58$ h, [36]) could fit the WISE data, and no other author published other results for this object, thus it deserves future studies.

(203015) 1999 YF3 is an Amor NEA of about 0.6 km (assuming 0.2 albedo) observed with the INT during only one available night in Feb 2020 (4 hours). Its raw plot looks quite scatered (Figure 4) but shows some growth of about 0.4 mag, based on which we suggest this relatively large object (0.582 km) to be a very slow rotator. There is no other period in the literature.

(418929) 2009 DM1 is a large 1.4 km diam Amor NEA targeted with the INT during only one available night in Sep 2018 (3 hours). Its raw data shows a growing trend (Figure 4), suggesting a lower tentative period limit

$P > 12\ h$ with a minimum amplitude $Amin = 0.05$ mag. This target was observed one month before us by Warner and Stephens during 5 nights [47] who proposed a solution ($P = 4.590 \pm 0.005$ h, $Amax = 0.17$ mag, order=4, U=2+) which does not confirm our growing trend, and the very small phase angle difference (3 deg) cannot explain the discrepancy.

(523587) 1999 VQ11 is a large Amor NEA of about 0.9 km (assuming albedo 0.2) targeted with the INT during only one available night in Sep 2018 for almost 3 hours which include the first 15 min of morning twilight. For most of the time, its raw curve seems to grow very slowly (below 0.1 mag), then it seems to descend quite abruptly during the last half hour (Figure 4). We discard the twilight influence, based on the similar error bars and our experience which has validated other 20-30 min twilight r-band observations. The small dataset was insufficient to attempt any period fit, nevertheless we can establish a lower tentative period limit, namely $P > 12$ h. Warner and Stephens observed this target during 11 nights [47], suggesting $P = 32.21 \pm 0.02$ h ($Amax = 0.79$ mag, order=4) but their solution is based on incomplete coverage and seems uncertain ($U = 2$).

5 Conclusions

We summarise here the main results of this survey, the fourth in a series of data papers aimed to increase the knowledge of the physical properties of NEAs mostly having no rotation information known before.

- During this campaign, we observed lightcurves of 52 NEAs (from which 13 were PHAs) using 10 telescopes available to the EURONEAR network.

- We proposed new periods or constraints for 20 targets (38% of the entire sample), namely: (66400), (96189) Pygmalion, (99799), (140333), (141484), (162882), (333555), (338347), (374188), (448818), (496005), (523611), (523630), (523824), (533541), 2008 LW16, 2011 LH, 2017 SO17, 2017 YH1 and 2018 CU1. Our periods confirm published data for 20 targets, while the proposed periods of 8 targets do not match published data.

- We secured periods for 15 targets (29% of the sample), candidate periods for 23 objects (44%), tentative periods for 11 asteroids (21%), and derived basic information about 3 targets with poor data which prevent any fitting (6% of the sample).

- We calculated the ellipsoid shape ratios a/b for 46 NEAs (including 13 PHAs).

- We confirmed or suggested the following 4 binary systems: (2059) Baboquivari (binary or tumbler observed poorly), (15745) Yuliya (secure binary), PHA (89959) and NEA (137170) (both candidate binaries which need future longer time observations).

- All data published in this paper was uploaded and is available in the ALCDEF database.

- The amount of work published in the four main papers and other related works during the last seven years in the entire EURONEAR lightcurve survey adds a total of 215 NEA lightcurves.

In the near future we plan to join our entire photometric work with other spectroscopic data published by Popescu et al. [23] and other work related to the same EURONEAR collaboration. By amalgamating our physical data with other similar literature data, we will be able to form a sample of about 250 NEAs possible to be studied in relation to the main belt (Radu Gherase, private communication).

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Finally, we express our deep sadness about Rebeca Galera Rosillo, IAC PhD student in planetary nebulae[10], who raised to the sky too young, during her ING studentship[11]. We will always remember her gentle smile and enthusiasm for supporting the INT operations, and in her memory the asteroid (77044) Galera-Rosillo will bear forever her name among the stars!

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[10] https://www.iac.es/en/outreach/news/iac-deeply-saddened-death-young-astrophysicist-rebeca-galera

[11] https://www.ing.iac.es//astronomy/rebeca.html

References

1. Adelman-McCarthy, J. K. et. al., *VizieR Online Data Catalog: The SDSS Photometric Catalog, Release 7*, Astrophysical Journal Supplement, 182, p. 543A (2009)
2. Astronomical Consultants & Equipment Inc., *ACE Control System. SARA CTIO 0.6-m Observatory User's Manual*, internal document, Feb 2015
3. Aznar Macias, A. et. al., *EURONEAR - First Lightcurves and Physical Properties of Near Earth Asteroids*, Romanian Journal of Physics, 62, 904, https://arxiv.org/pdf/1801.09420 (2017)
4. Aznar Macias, A., *Propiedades fisicas del NEA binario 5143 Heracles* (in Spanish), AstronomíA Magazine, 215, p. 44 (May 2017)
5. Aznar Macias, A. et al., *Binary asteroid discovery IAU announcement*, CBET 4523, 1A; also online https://aptog.com/?p=454 (2018b)
6. Aznar Macias, A. et al., *Physical properties of PHA 2014 JO25 from a worldwide observational campaign*, Monthly Notices of the Royal Astronomical Society, 483, 4820A (2019)
7. Benishek, V. and Pravec, P. *Redetermined Orbital Period for the Newly Discovered Near-Earth Binary Asteroid 15745 Yuliya*, The Minor Planet Bulletin, vol. 45, no. 4, p. 336 (2018)
8. Bertin, E., *AstrOmatic Software in the Era of Large Stellar Photometric Surveys*, Star Clusters in the Era of Large Surveys, Astrophysics and Space Science Proceedings, p. 71, Springer-Verlag Berlin Heidelberg (2012)
9. Birlan, M. et al. *Characterization of (357439) 2004 BL86 on its close approach to Earth in 2015*, Astronomy and Astrophysics, vol. 581, p. A3 (2015)
10. , Chambers, K. C. et al., *The Pan-STARRS1 Surveys*, arXiv eprint arXiv:1612.05560
11. Char, F. et al., *Ckoirama, the first Chilean-state owned observatory under desert skies*, Boletin de la Asociacion Argentina de Astronomia, vol. 58, p. 200 (2016)
12. Durech, J. et al., *Analysis of the rotation period of asteroids (1865) Cerberus, (2100) Ra-Shalom, and (3103) Eger – search for the YORP effect*, Astronomy and Astrophysics, vol. 547, p. A10 (2012)
13. Franco, B. et al., *Lightcurves for 1318 Nerina, 1342 Brabantia 1981 Midas, and 3951 Zichichi*, The Minor Planet Bulletin, vol. 45, p. 273F (2018)
14. Hanus, J. et al., *Thermophysical modeling of asteroids from WISE thermal infrared data - Significance of the shape model and the pole orientation uncertainties*, Icarus, vol. 256, p. 101 (2015)
15. Henden, A. A., et al., *VizieR Online Data Catalog: AAVSO Photometric All Sky Survey (APASS) DR9*, VizieR On-line Data Catalog: II/336. Originally published in AAS Meeting 225, id.336.16 (2016)
16. Keel, W. C. et al., *The Remote Observatories of the Southeastern Association for Research in Astronomy (SARA)*, Publications of the Astronomical Society of the Pacific, 129, 971, pp. 015002
17. Lang, D. et al., *Astrometry.net: Blind astrometric calibration of arbitrary astronomical images*, The Astronomical Journal 139, p. 1782
18. Marchis, F. et al., *Multiple asteroid systems: Dimensions and thermal properties from Spitzer Space Telescope and ground-based observations*, Icarus, Vol 221, 2, p. 1130, 2012
19. Mottola, S. et al., *The EUNEASO Photometric Follow-up Program*, Lunar and Planetary Science Conference, Vol 26, p. 1003, 1995
20. Ochsenbein, F. et al., *The VizieR database of astronomical catalogues*, Astronomy and Astrophysics Supplement, Volume 143, p. 23
21. Pal, A. et al., *Solar System Objects Observed with TESS—First Data Release: Bright Main-belt and Trojan Asteroids from the Southern Survey*, Astrophysical Journal Supplement Series, Volume 247, Issue 1, id. 26, 9 (2020)
22. Persson, S. E. et al., *Las-Campanas Observatory Seeing Measurements*, Experimental Astronomy, Volume 1, 3, pp. 195 (1990)
23. Popescu, M. et al., *Near-Earth asteroids spectroscopic survey at Isaac Newton Telescope*, Astronomy and Astrophysics, 627, 124 (2019)
24. Pozo Nunez, F. et al., *Automatized Photometric Monitoring of Active Galactic Nuclei with the 46 cm Telescope of the Wise Observatory*, Publications of the Astronomical Society of the Pacific, vol. 129, p. 979 (2017)
25. Pravec, P. et al., *Two Periods of 1999 HF1 - Another Binary NEA Candidate*, Icarus, Vol 158, 1, p. 276 (2002)
26. Pravec, P. et al., *Photometric survey of binary near-Earth asteroids*, Icarus, Vol 181, 1, p. 63 (2006)
27. Skiff, B. et al., *Lowell Observatory Near-Earth Asteroid Photometric Survey (NEAPS): Paper 4*, The Minor Planet Bulletin, vol. 46, p. 458 (2019)
28. Sonka, A. et al., *New Photometric Observations of the Binary Near-Earth Asteroid (137170) 1999 HF1*, The Minor Planet Bulletin, vol. 41, 4, p. 285 (2014)
29. Sonka, A. et al., *Photometric Observations of the Near-Earth Asteroids (326683) 2002 WP and 2016 LX48*, The Minor Planet Bulletin, vol. 44, 3, p. 176 (2017a)
30. Sonka, A. et al., *Photometric observations of Near Earth Asteroid 2012 TC4*, Romanian Astronomical Journal, vol. 27, 3, p. 223 (2017b)
31. Sonka, A. et al., *Photometric Monitoring of PHA (3122) Florence*, Romanian Astronomical Journal, vol. 28, 2, p. 79 (2018)
32. Sonka, A. et al., *The (155140) 2005 UD lightcurve and rotational period from simultaneous observations*, Romanian Astronomical Journal, vol. 29, 1, p. 33 (2019a)
33. Sonka, A. et al., *Photometry of binary Near Earth Asteroid (66391) 1999 KW4*, Romanian Astronomical Journal, vol. 29, 2, p. 157 (2019b)
34. Sonka, A. et al., *Fast Rotator Minor Planet 2020 UA From Cluj and Berthelot Observatory*, Minor Planet Bulletin, vol. 48, 2, p. 100 (2021a)
35. Sonka, A. et al., *Photometric observations of Low Delta v asteroids*, Romanian Astronomical Journal, vol. 31, 3, p. 293 (2021b)
36. Vaduvescu, O. et. al., *The EURONEAR Lightcurve Survey of Near Earth Asteroids*, Earth, Moon, and Planets, 120, 2, 41 (2017)
37. Vaduvescu, O. and Aznar Macias, A., *Lightcurve of NEA 1993 RA*, The Minor Planet Bulletin, vol. 45, nr. 1, p. 96 (2018)
38. Vaduvescu, O. et al, *Dozens of virtual impactor orbits eliminated by the EURONEAR VIMP DECam data mining project*, Astronomy and Astrophysics, vol. 642, p. A35 (2020)
39. Vaduvescu, O. et. al., *The EURONEAR Lightcurve Survey of Near Earth Asteroids - Teide Observatory, Tenerife, 2015*, Earth, Moon, and Planets, 125, 2, 3 (2021)
40. Zappala V. et al, *An analysis of the amplitude-phase relationship among asteroids*, Astronomy and Astrophysics, vol. 231, p. 548 (1990)
41. Warner, B., *The asteroid lightcurve database*, Icarus, vol. 202, 1, p. 134 (2009)
42. Warner, B., *Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 Apr-Jul*, The Minor Planet Bulletin, vol. 43, p. 311 (2016a)
43. Warner, B., *Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 Apr-Jul*, The Minor Planet Bulletin, vol. 43, p. 66 (2016b)

44. Warner, B., *Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2018 Jan-Apr*, The Minor Planet Bulletin, vol. 45, p. 248 (2018a)
45. Warner, B., *Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2018 Apr-Jun*, The Minor Planet Bulletin, vol. 45, p. 366 (2018b)
46. Warner, B., *Near Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2018 Jul-Sep*, The Minor Planet Bulletin, vol. 46, p. 24 (2019a)
47. Warner, B., *Near Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2018 Jul-Sep*, The Minor Planet Bulletin, vol. 46, p. 27 (2019b)
48. Warner, B. & Stephens, R., *Near-Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2019 Mar-Jul*, The Minor Planet Bulletin, vol. 46, p. 423 (2019c)
49. Warner, B. & Stephens, R., *Near-Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2018 Sep-Dec*, The Minor Planet Bulletin, vol. 46, p. 144 (2019d)
50. Warner, B. & Stephens, R., *Near-Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2019 January-April*, The Minor Planet Bulletin, vol. 46, p. 304 (2019e)
51. Warner, B. and Stephens, R., *Near Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2019 Jul-Sep*, The Minor Planet Bulletin, vol. 47, p. 23 (2020a)
52. Warner, B. and Stephens, R., *Near Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2020 Apr-Jun*, The Minor Planet Bulletin, vol. 47, p. 290 (2020b)
53. Warner, B. and Stephens, R., *Near Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2019 Sep - 2020 Jan*, The Minor Planet Bulletin, vol. 47, p. 105 (2020c)
54. Wisniewski, W. Z. et al, *Photometric Observations of 125 Asteroids*, Icarus, vol. 126, 2, p. 395 (1997)

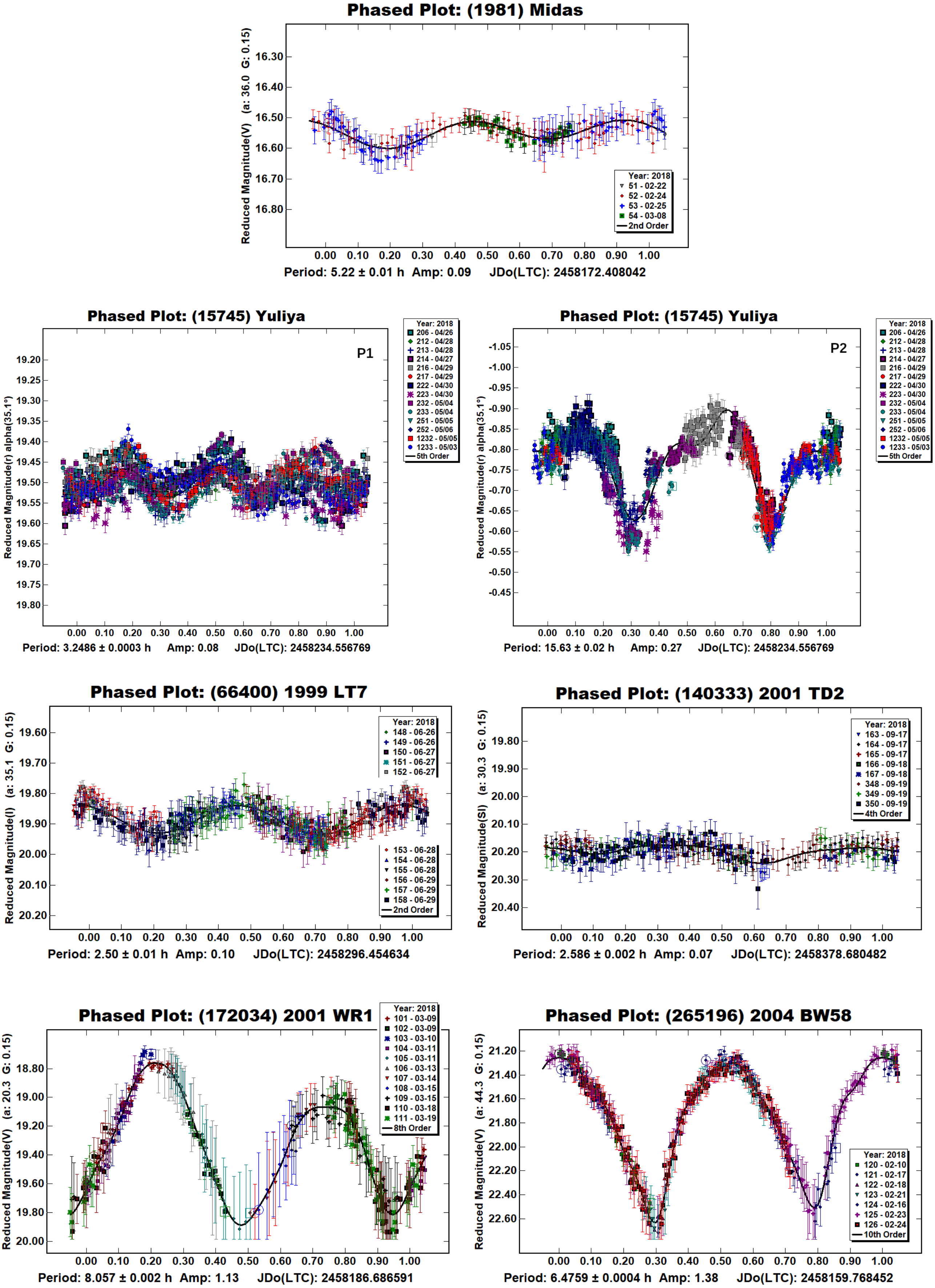

Figure 1: Lightcurves of NEAs resolved with secure periods.

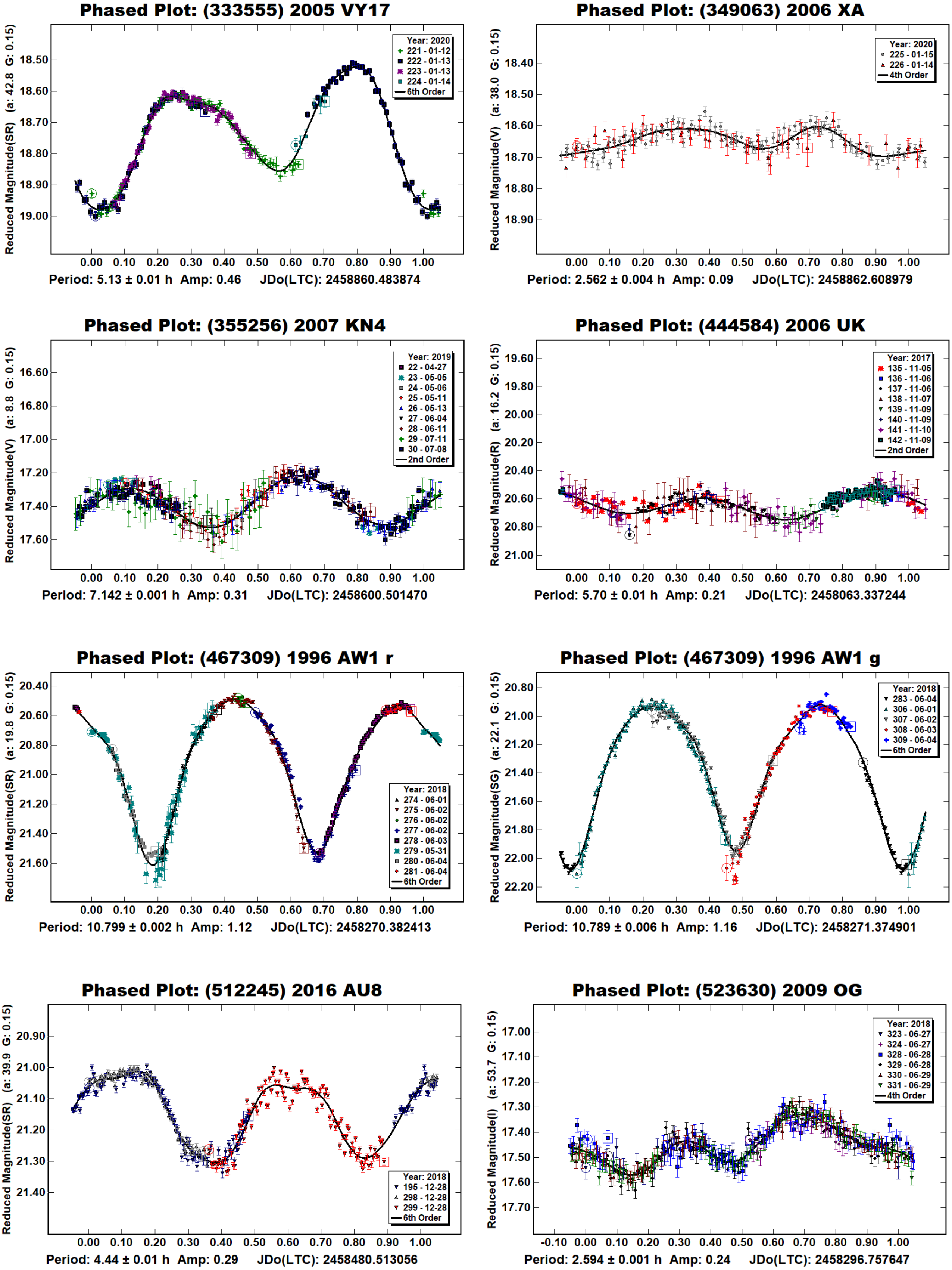

Figure 1 (continued): Lightcurves of NEAs resolved with secure periods.

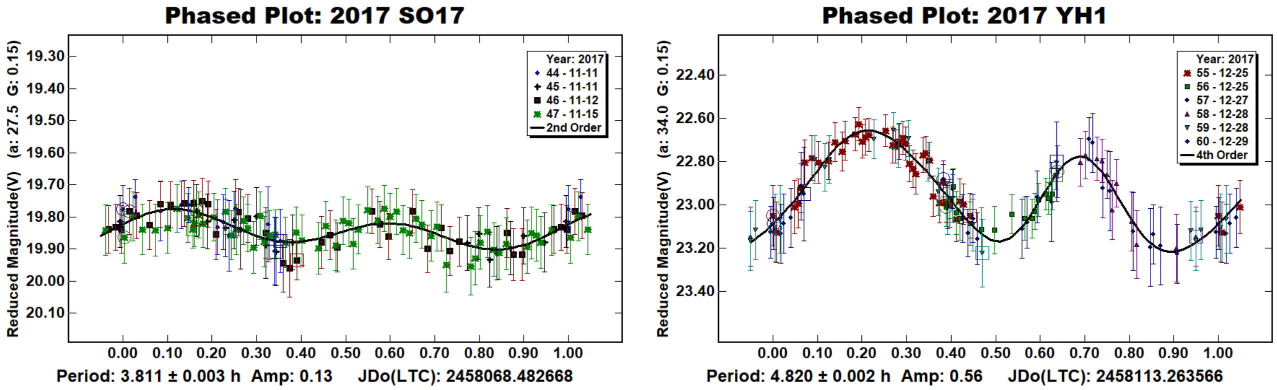

Figure 1 (continued): Lightcurves of NEAs resolved with secure periods.

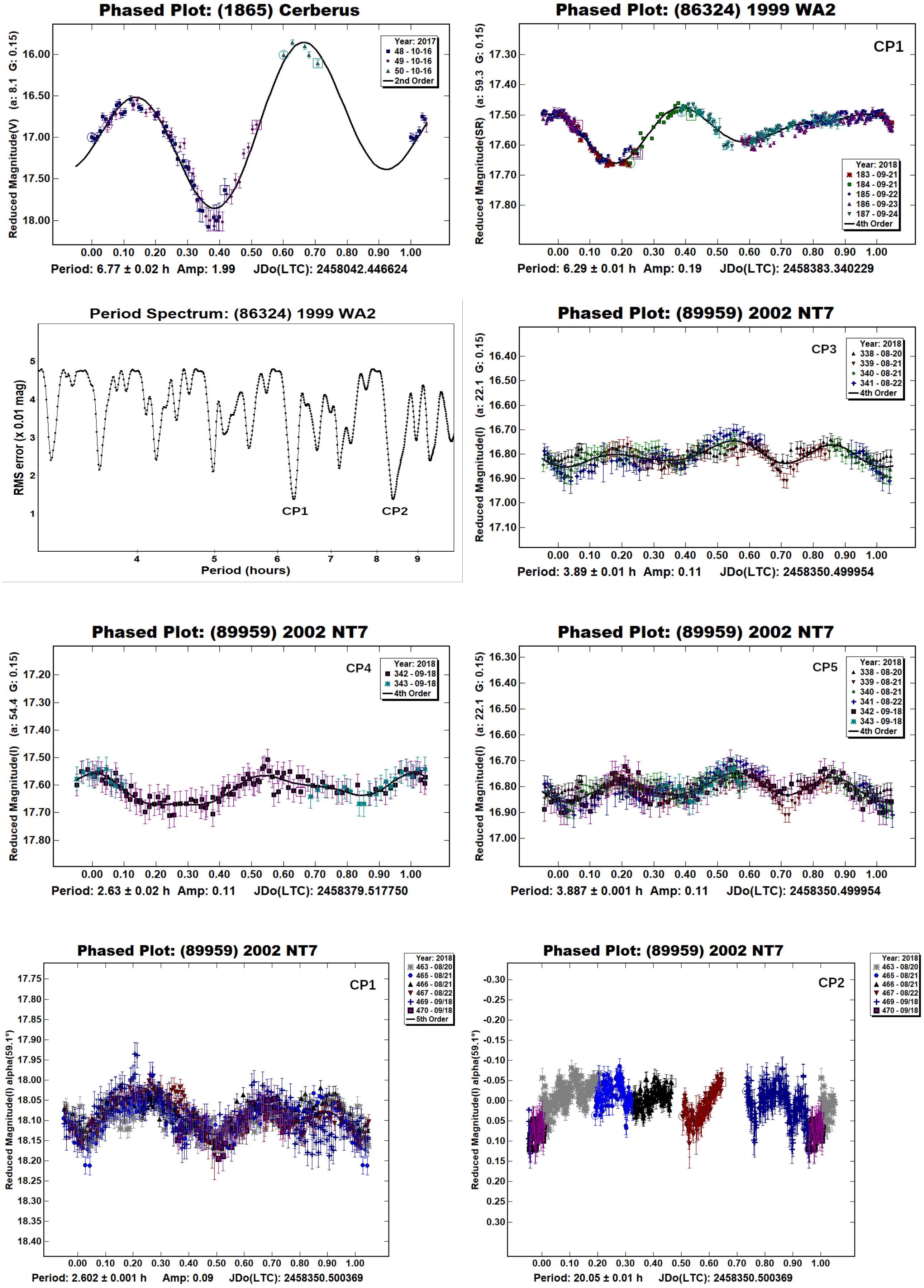

Figure 2: Lightcurves of NEAs resolved with candidate periods.

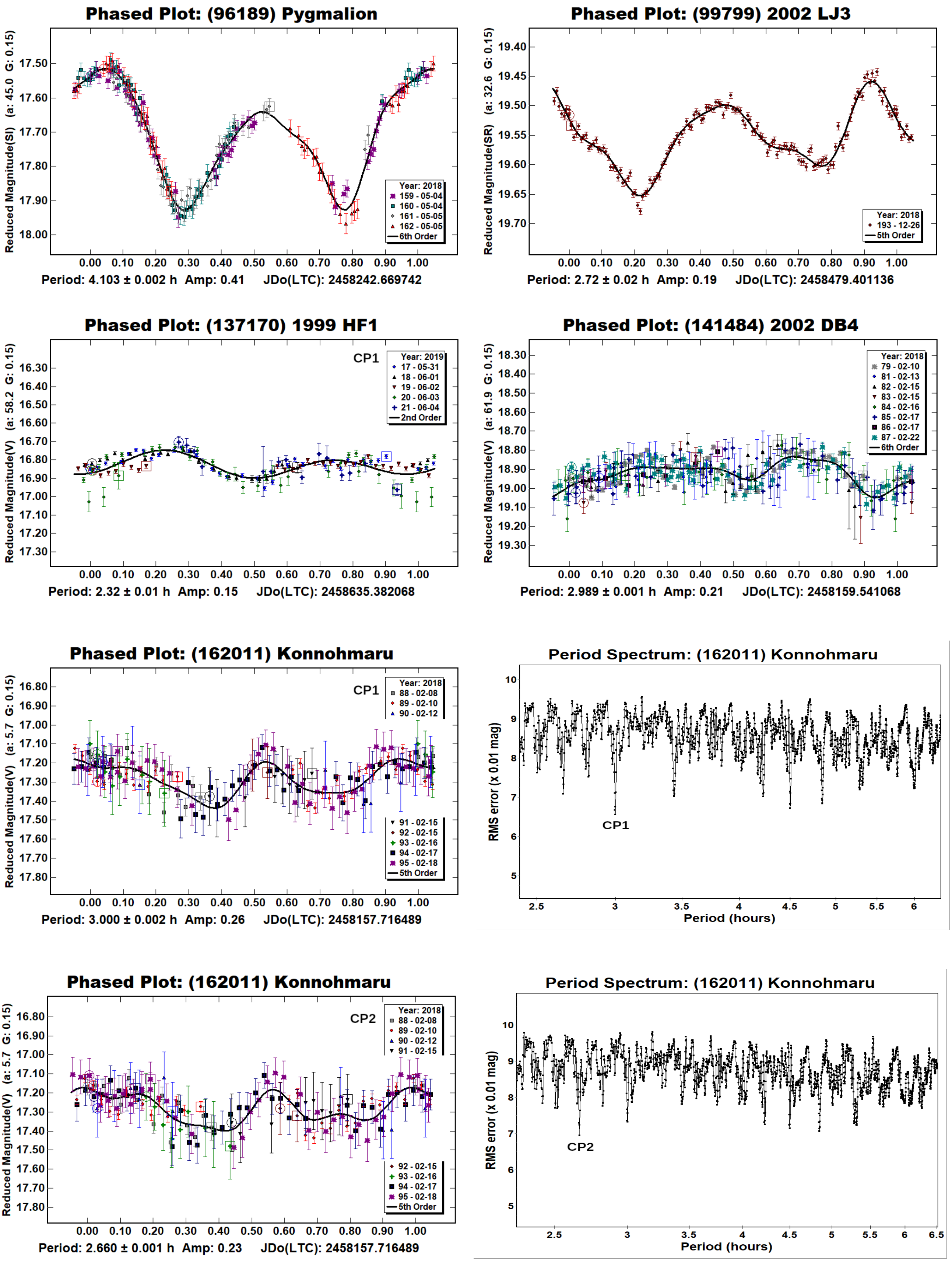

Figure 2 (continued): Lightcurves of NEAs resolved with candidate periods.

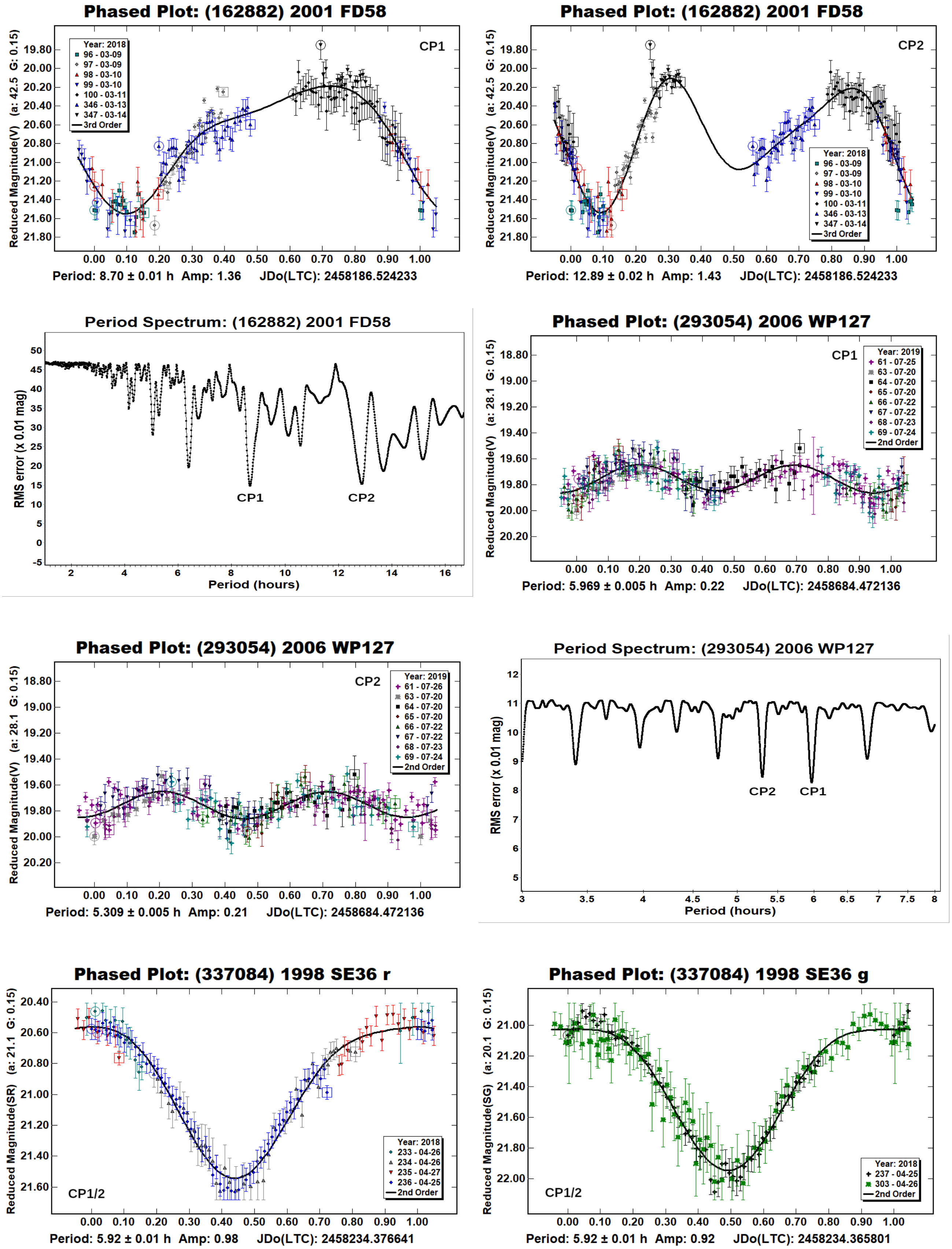

Figure 2 (continued): Lightcurves of NEAs resolved with candidate periods.

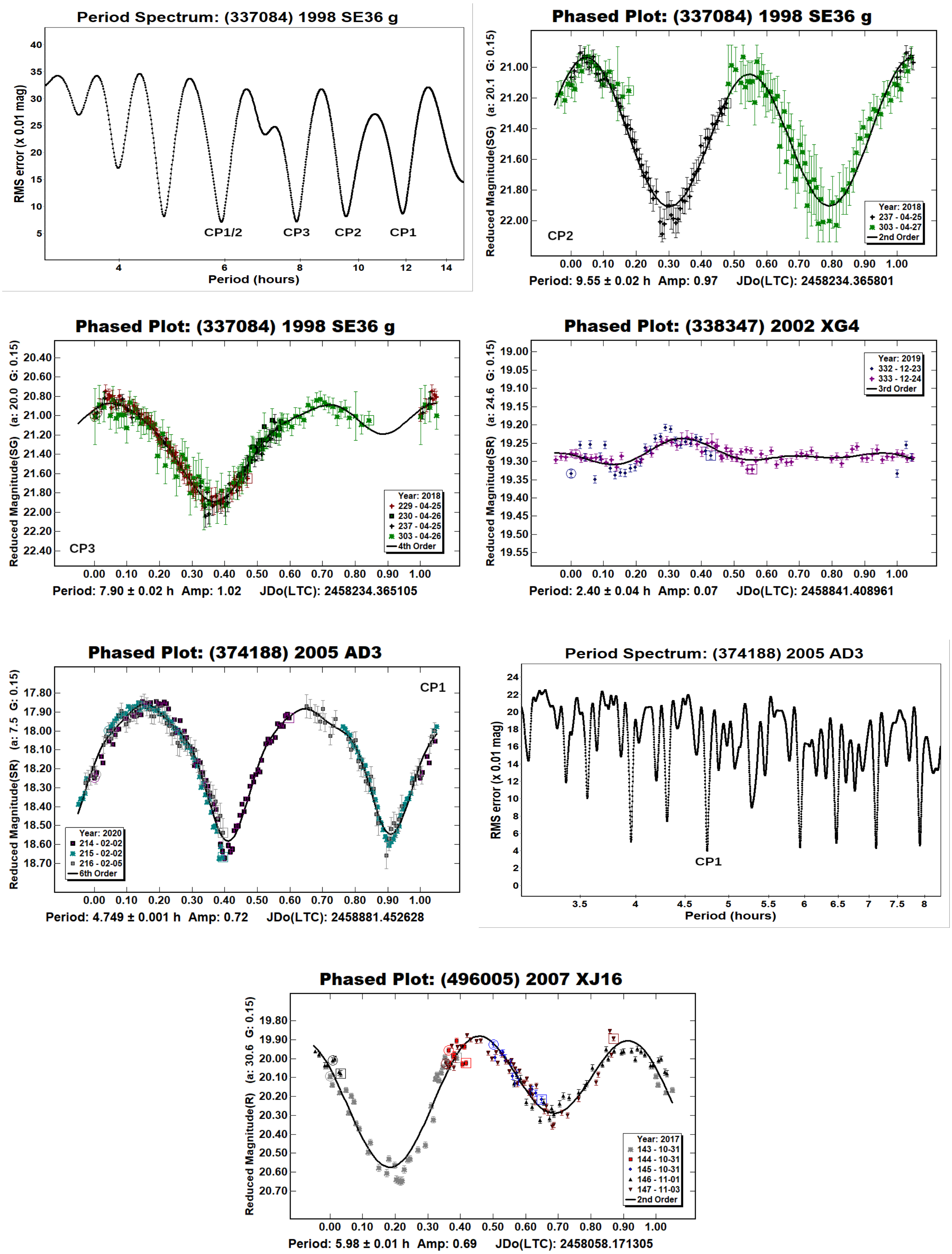

Figure 2 (continued): Lightcurves of NEAs resolved with candidate periods.

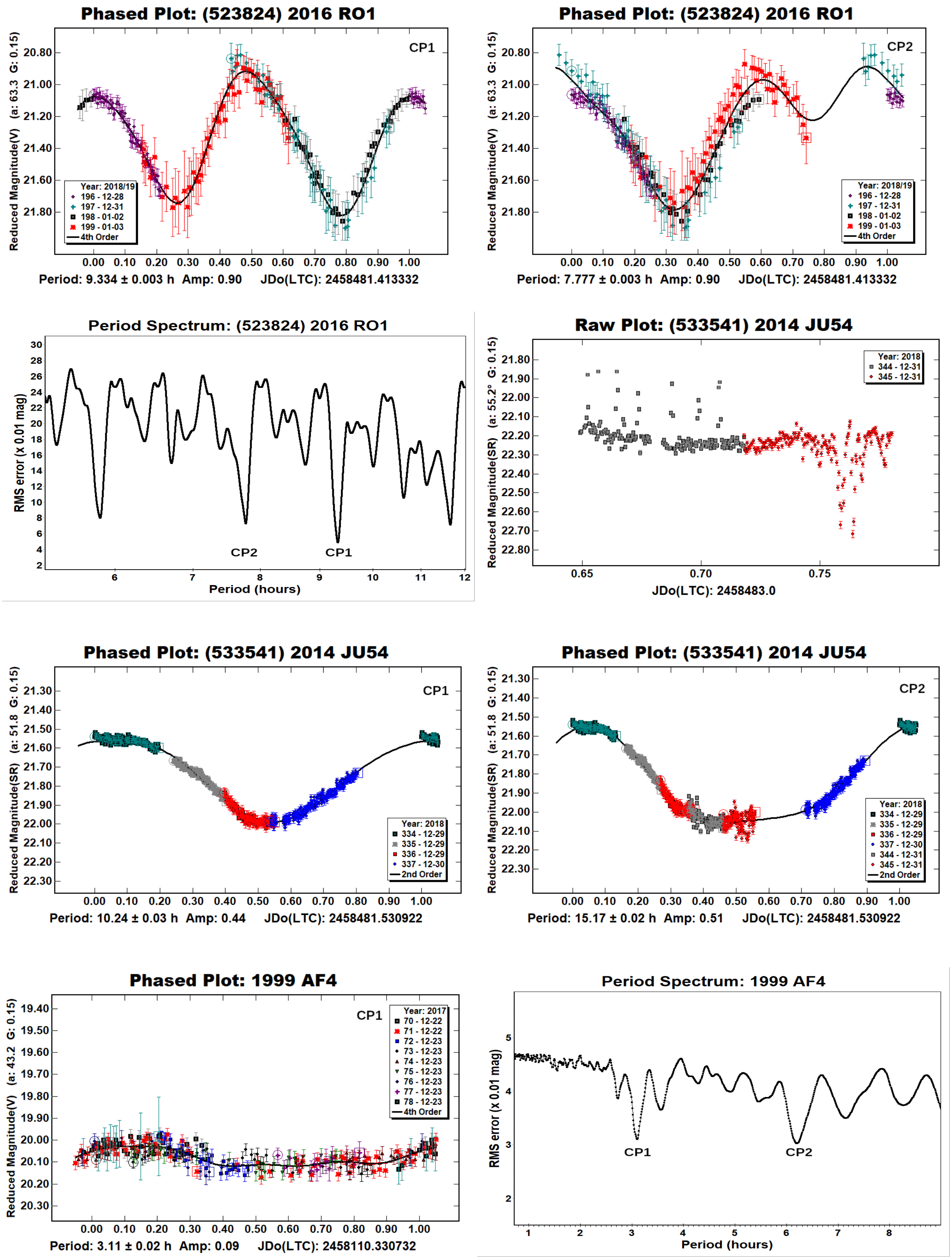

Figure 2 (continued): Lightcurves of NEAs resolved with candidate periods.

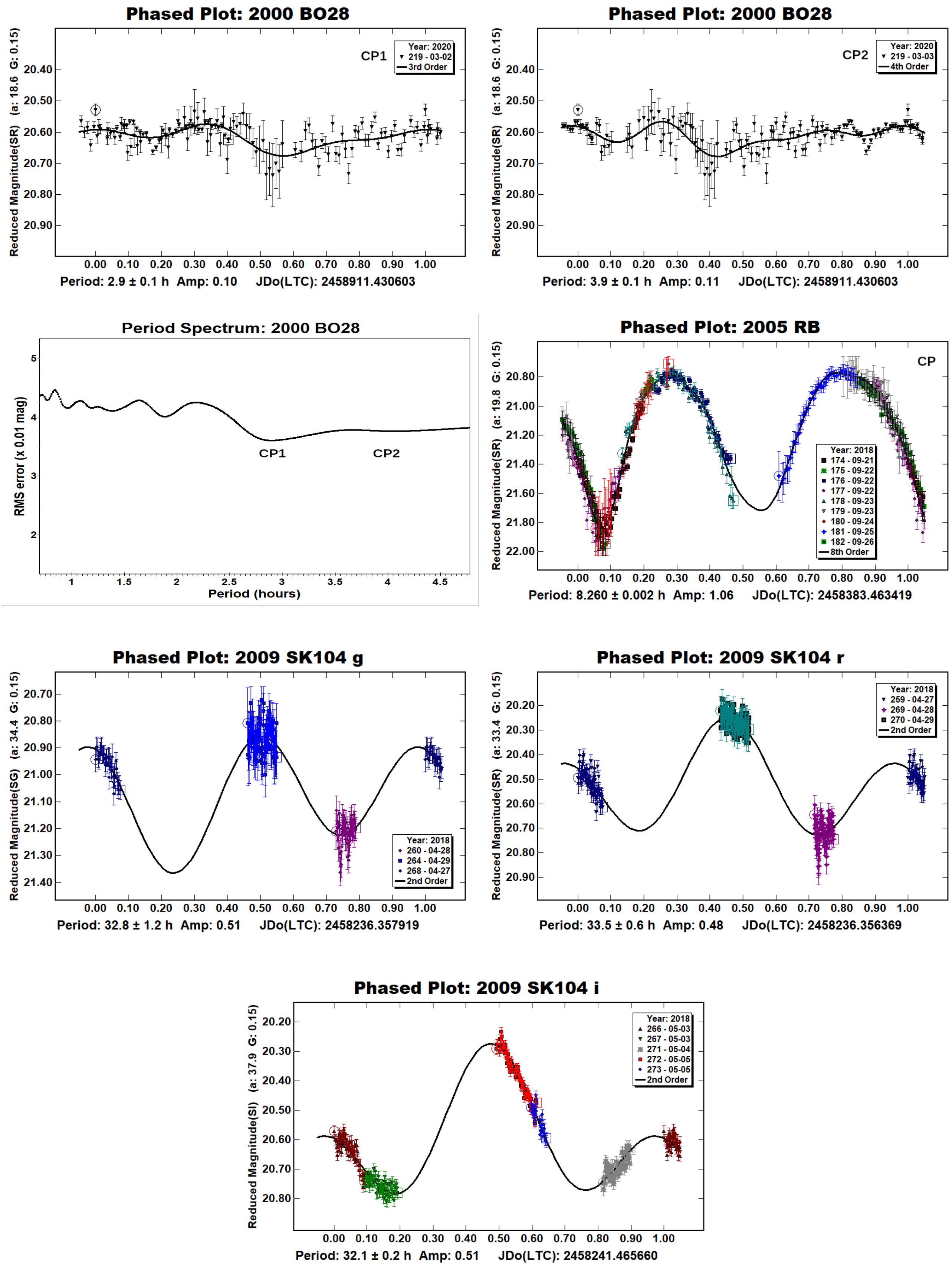

Figure 2 (continued): Lightcurves of NEAs resolved with candidate periods.

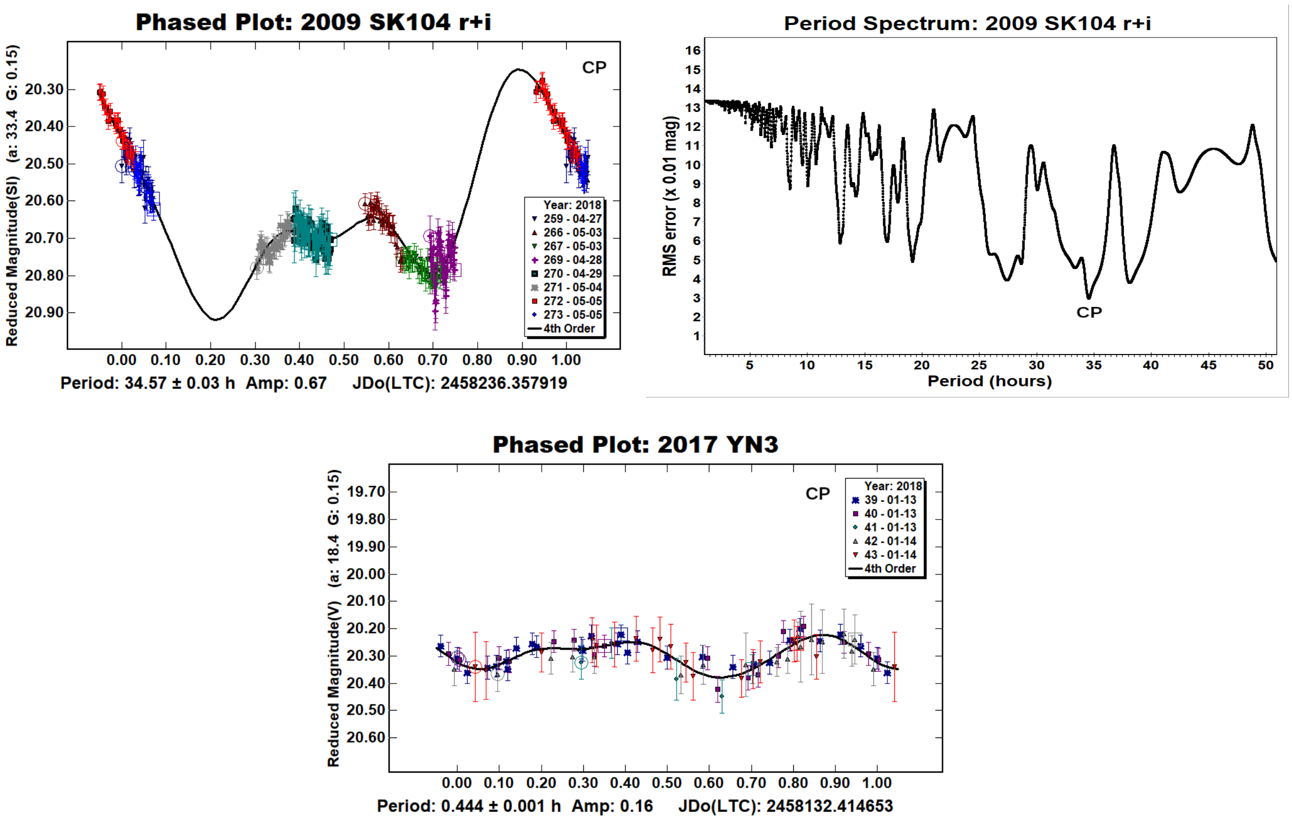

Figure 2 (continued): Lightcurves of NEAs resolved with candidate periods.

6 APPENDIX - Plots of Poorly Observed Objects

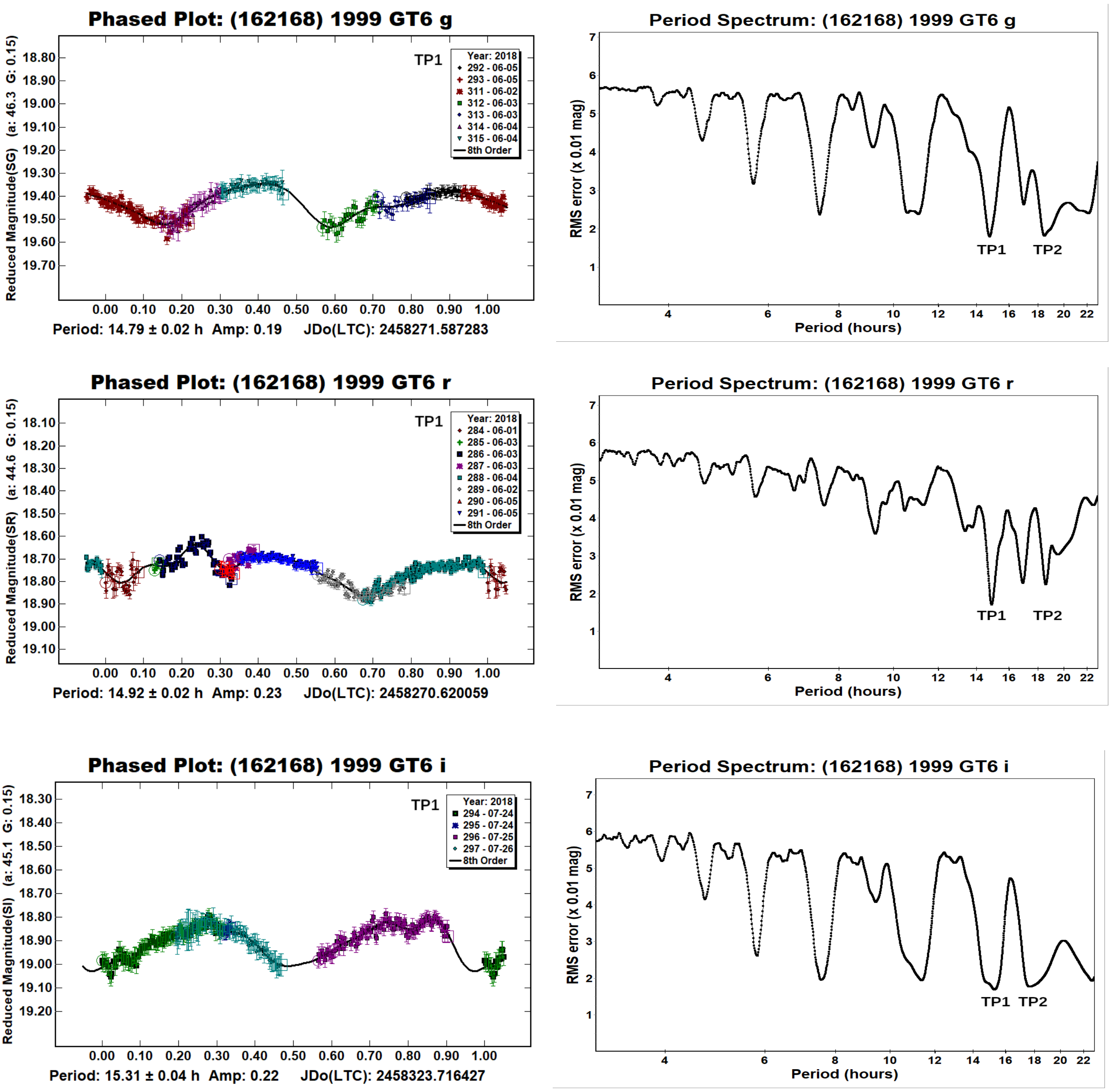

Figure 3: Lightcurves of NEAs poorly observed with tentative periods.

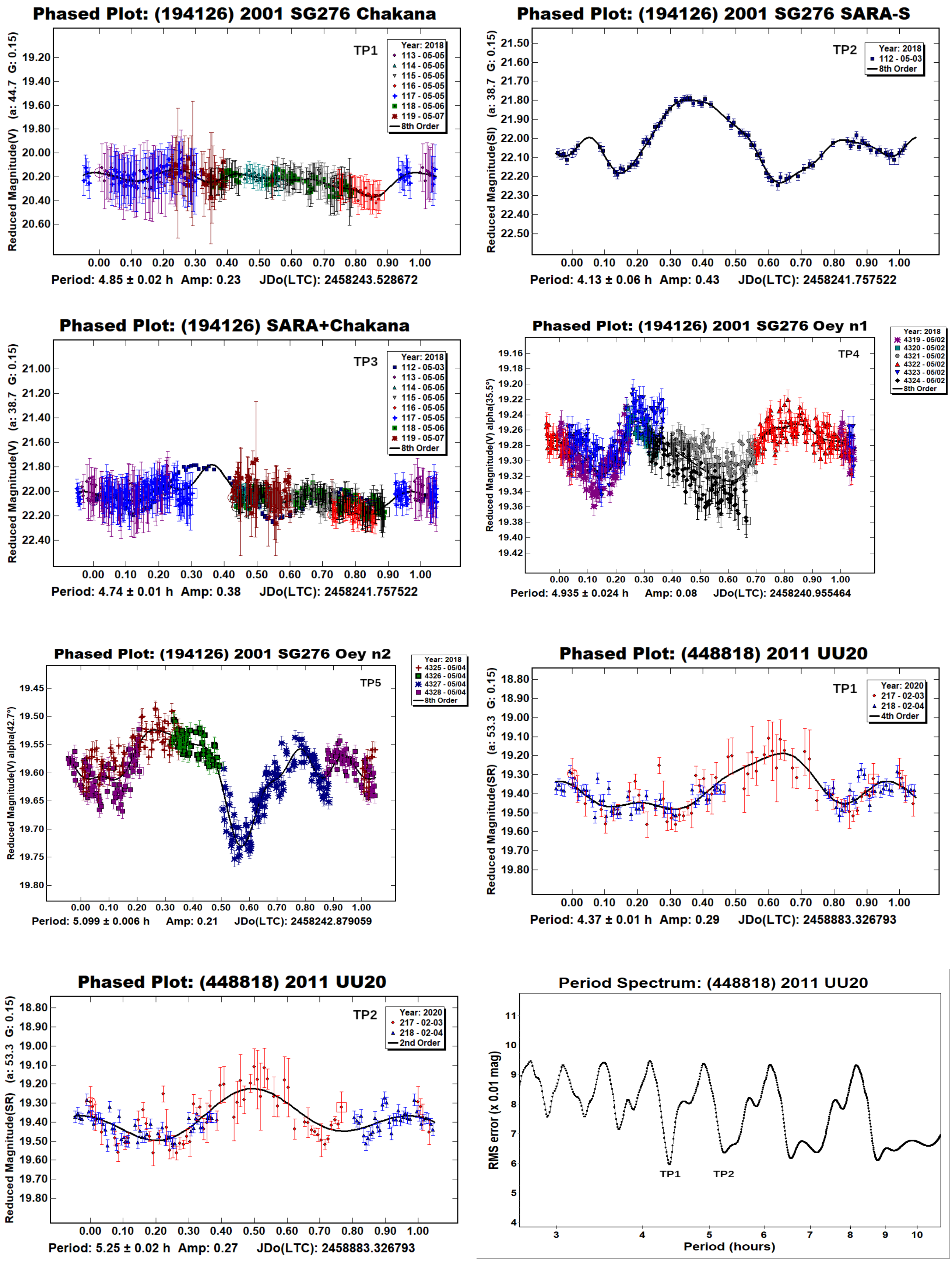

Figure 3 (continued): Lightcurves of NEAs poorly observed with tentative periods.

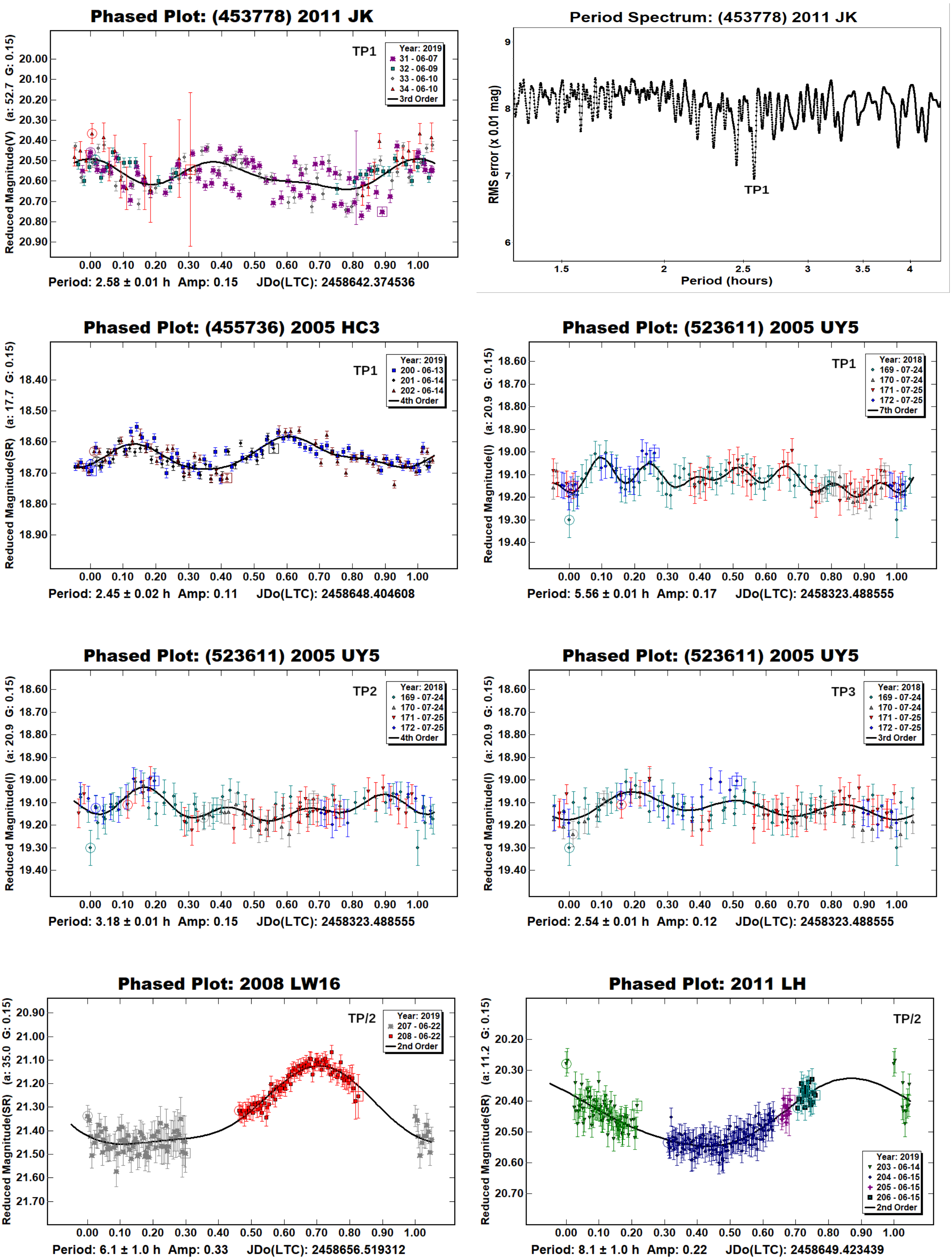

Figure 3 (continued): Lightcurves of NEAs poorly observed with tentative periods.

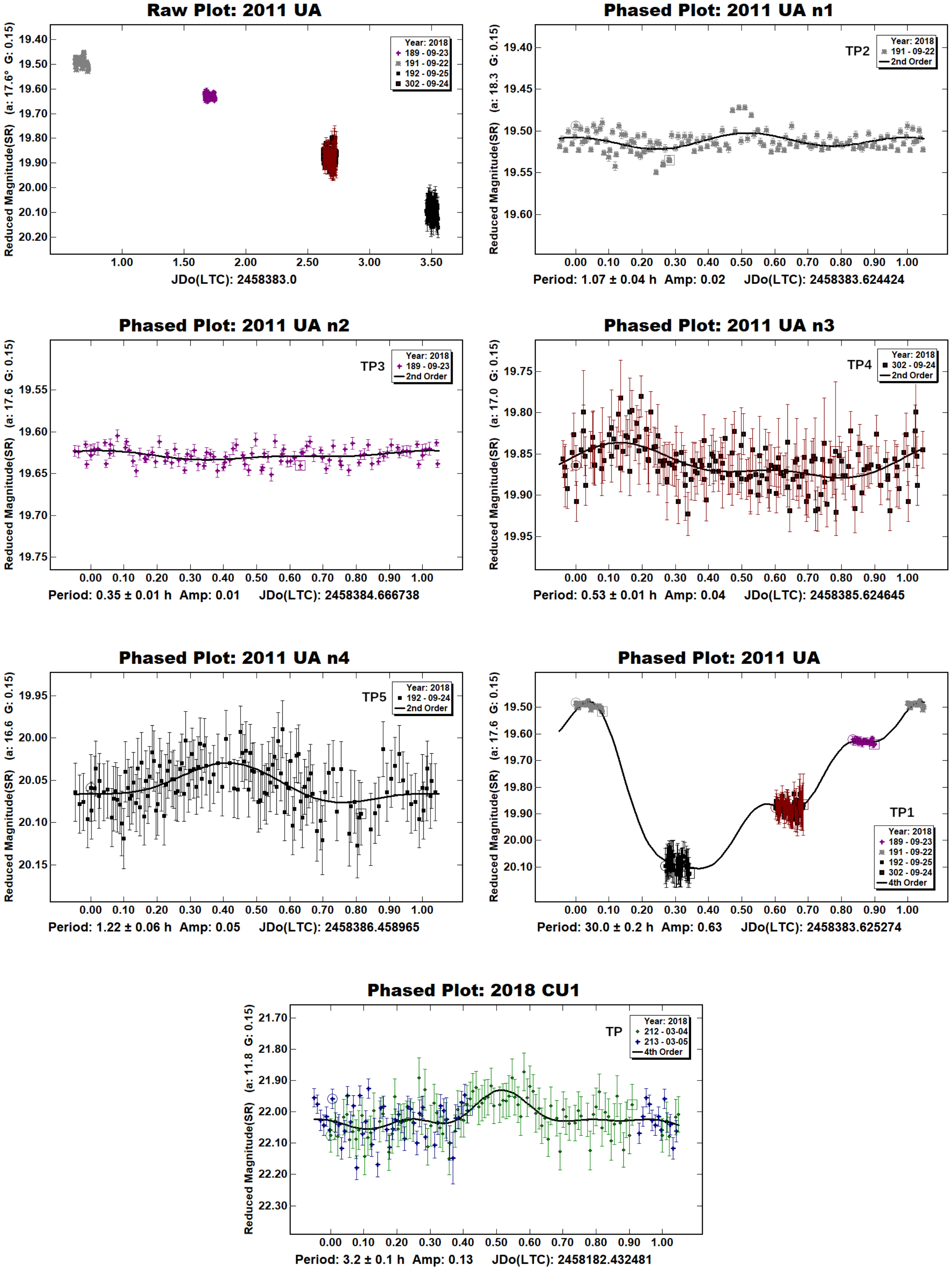

Figure 3 (continued): Lightcurves of NEAs poorly observed with tentative periods.

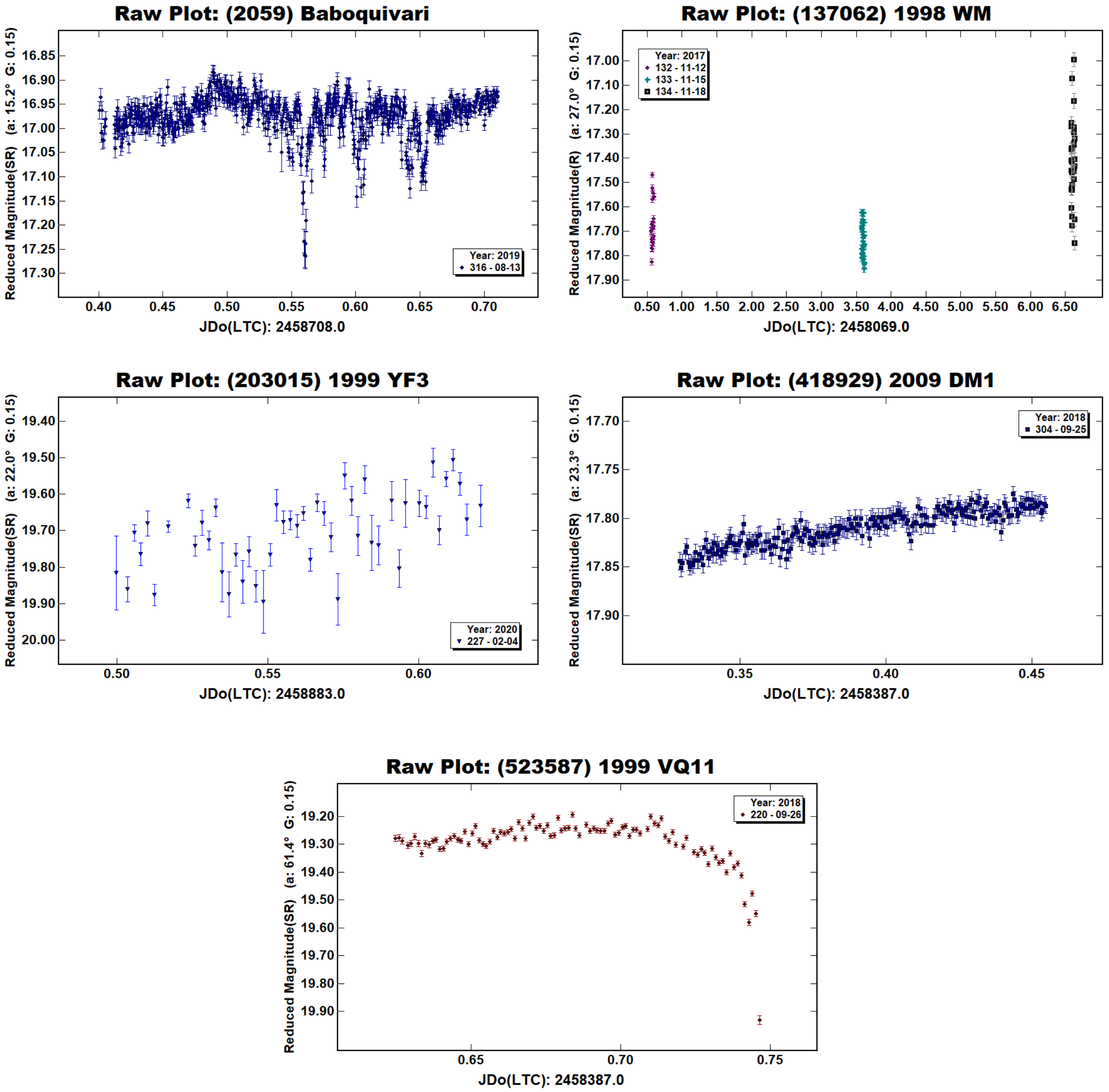

Figure 4: Lightcurves of NEAs poorly observed without periods.