

LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2021 JANUARY-MARCH

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We present lists of asteroid photometry opportunities for objects reaching a favorable apparition and have no or poorly-defined lightcurve parameters. Additional data on these objects will help with shape and spin axis modeling using lightcurve inversion. We also include lists of objects that will or might be radar targets. Lightcurves for these objects can help constrain pole solutions and/or remove rotation period ambiguities that might come from using radar data alone.

On Better Magnitude Calibrations and H-G Data Requirements

In recent times, several catalogs with high-quality photometry have become available. A major advantage of these catalogs for lightcurve observers is the significant reduction of systematic variations for magnitude calibrations across the sky. This has led to fewer and much smaller nightly zero-point adjustments when trying to do photometric analyses.

An excellent example of taking advantage of these new resources was given by Eric Dose (2021), who developed a pipeline using the ATLAS Star Catalog (Tonry et al., 2018). Other catalogs such as Pan-STARRS, SkyMapper, and GAIA2 can be readily accessed with on-line tools to get comparison star magnitudes for a given field. This, of course, requires that an Internet connection be available at some point, either before, during, or after the initial reduction process.

The elimination, or significant reduction, of arbitrary zero-point adjustments is critical when trying to find H-G or H-G₁₂ parameters. For asteroid lightcurves, even small zero-point changes can dramatically change a period solution, especially when the amplitude is low. The adjustments can also alter results when dealing with tumbling or binary asteroids.

We *strongly* suggest that all observers adopt one of the above-mentioned catalogs as their exclusive source for comparison star magnitudes as soon as possible. We also recommend that the native magnitudes of the chosen catalog be used. For example, from ATLAS or Pan-STARRS, the r' (Sloan SR) magnitude, and not magnitudes that are the result of applying transformations that use a simple constant offset or color index dependency on two of the native magnitudes, e.g., SG/SR to Rc.

The SR magnitudes should be used when observing without (or with a Clear) filter and typical CCD cameras (e.g., FLI, SBIG, etc.) with a KAF-E chip (blue enhanced) or another chip with similar response. This is because those chips have a very good linear fit of catalog versus instrumental magnitude for the Rc and SR bands and so, if using near-solar color stars, there is no need for additional reductions such as color term correction.

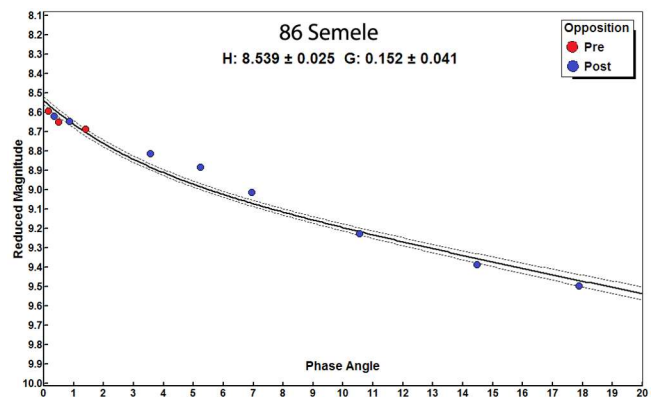
Regarding H-G observations, the question of how much data is enough is often raised. The answer is, “It depends on the nature of the observing project.” To that, we’d add that having just a few data points at each observing run places a much greater demand on having accurate magnitudes. If those requirements are on the order of ≤ 0.02 mag, that stretches the limits even when using the high-quality catalogs.

The H-G system is based on average light at the time of the observations, i.e., the amplitude of the lightcurve at the time must be known and, if necessary, those few data points be corrected so that they correspond to “mid-light” at the time. Since the amplitude often changes as the asteroid recedes or approaches, it’s necessary to obtain enough data points during each observing run to establish or reasonably predict the mid-light magnitude.

Another reason for denser data sets is that the results from shape modeling are greatly improved by having good lightcurves from multiple phase angles within the same apparition. This is in addition to lightcurves obtained over several apparitions.

There is no set answer to the number of data points, exposure length, observing cadence that satisfies all purposes. However, it might be good to remember that you can always disregard or reject data points during analysis but you can’t create them after the fact.

A good example of balancing the number of H-G data points and those needed to derive those points can be seen in the lightcurves and H-G plot (a modified version is shown here) for 86 Semele by Frederick Pilcher (2020).



The original plot by Pilcher (2020) has been modified to make the data points easier to see and a legend replaces the explanatory text for the data points.

A final note, the H in the H-G system is, by default, Johnson V. For direct comparisons with other reported H values, it may be necessary to use a transform to go from the native magnitude used from the catalog. The web pages for the catalog used in reductions may provide or have links to the required transformation formulae.

Back to Regular Programming

We present several lists of asteroids that are prime targets for photometry during the period 2021 January-March.

In the first three sets of tables, “Dec” is the declination and “U” is the quality code of the lightcurve. See the latest asteroid lightcurve data base (LCDB from here on; Warner et al., 2009a) documentation for an explanation of the U code:

<http://www.minorplanet.info/lightcurvedatabase.html>

The ephemeris generator on the CALL web site allows you to create custom lists for objects reaching $V \leq 18.0$ during any month in the current year and up to five years in the future, e.g., limiting the results by magnitude and declination, family, and more:

http://www.minorplanet.info/PHP/call_OppLCDBQuery.php

We refer you to past articles, e.g., Warner et al. (2009b) for more detailed discussions about the individual lists and points of advice regarding observations for objects in each list.

Once you’ve obtained and analyzed your data, it’s important to publish your results. Papers appearing in the *Minor Planet Bulletin* are indexed in the Astrophysical Data System (ADS) and so can be referenced by others in subsequent papers. It’s also important to make the data available at least on a personal website or upon request. We urge you to consider submitting your raw data to the ALCDEF database. This can be accessed for uploading and downloading data at:

<http://www.alcdef.org>

Containing almost 3.8 million observations for 15,000+ objects (2020 October 5), this makes the site one of the larger publicly available sources for raw asteroid time-series lightcurve data.

Now that many backyard astronomers and small colleges have access to larger telescopes, we have expanded the photometry opportunities and spin axis lists to include asteroids reaching $V = 15.5$ and brighter (sometimes 15.0 when the list has too many potential targets).

Lightcurve/Photometry Opportunities

Objects with $U = 3-$ or 3 are excluded from this list since they will likely appear in the list for shape and spin axis modeling. Those asteroids rated $U = 1$ should be given higher priority over those rated $U = 2$ or $2+$, but not necessarily over those with no period. On the other hand, *do not overlook asteroids with $U = 2/2+$ on the assumption that the period is sufficiently established.* Regardless, do not let the existing period influence your analysis since even highly-rated result have been proven wrong at times. Note that the lightcurve amplitude in the tables could be more or less than what’s given. Use the listing only as a guide.

An entry in bold italics is a near-Earth asteroid (NEA).

Number	Name	Brightest			LCDB Data		
		Date	Mag	Dec	Period	Amp	U
6821	Ranevskaya	01	02.0	15.2 +13	2.81	0.10	2+
26520	2000 CQ75	01	04.4	15.2 +15	3.97	0.37	2
18640	1998 EF9	01	05.5	15.0 +6			
1479	Inkeri	01	07.7	14.4 +35	660.	1.30	2+
2277	Moreau	01	07.8	14.9 +23	> 12.	0.08	2-
1844	Susilva	01	08.9	15.0 +25			
8648	Salix	01	09.0	15.2 +14			
332446	2008 AF4	01	09.8	14.3 +13			

Number	Name	Brightest			LCDB Data		
		Date	Mag	Dec	Period	Amp	U
26206	1997 PJ4	01	15.2	15.4 +16			
2984	Chaucer	01	15.2	15.4 +24			
3590	Holst	01	22.8	15.0 +18	12.7635	0.20	2
13709	1998 QE13	01	25.5	15.2 +17	55.961		2
4612	Greenstein	01	28.8	15.3 +25			
2546	Libitina	02	01.9	14.3 +18	132.71	0.35	2+
174050	2002 CC19	02	03.8	14.0 +17			
87035	2000 KE2	02	04.3	15.5 +20			
1612	Hirose	02	12.8	14.8 +12	12.295	0.25	2
1724	Vladimir	02	14.0	14.8 +7	12.582	0.14-0.24	2+
5348	Kennoguchi	02	17.1	15.5 +7			
1513	Matra	02	17.1	14.8 +14	> 24.	0.1	1
13521	1991 BK	02	19.7	15.5 +21			
4107	Rufino	02	21.6	14.4 +13	15.31	0.07-0.15	2
5982	Polykletus	02	28.7	15.5 +0			
49483	1999 BP13	03	01.9	15.1 +7			
4133	Heureka	03	03.3	15.3 +1			
2288	Karolinum	03	05.0	14.4 +29	42.16	0.15-0.40	2+
2521	Heidi	03	05.4	15.1 -5	12.	0.02	1
4238	Audrey	03	07.7	15.5 +6			
2777	Shukshin	03	10.0	15.3 +10			
22295	1989 SZ9	03	16.6	15.5 +4	3.8	0.04	2
3748	Tatum	03	20.7	15.0 +6	58.21	0.54	2+
4794	Bogard	03	20.9	15.5 +1			
7685	1997 EP17	03	21.7	15.3 -3			
7637	1984 DN	03	25.1	15.5 +5			
10859	1995 GJ7	03	27.5	15.3 +0			
9967	Awanoyumi	03	29.6	15.3 +6			

Low Phase Angle Opportunities

The Low Phase Angle list includes asteroids that reach very low phase angles ($\alpha < 1^\circ$). The “ α ” column is the minimum solar phase angle for the asteroid. Getting accurate, calibrated measurements (usually V band) at or very near the day of opposition can provide important information for those studying the “opposition effect.” Use the on-line query form for the LCDB to get more details about a specific asteroid:

http://www.minorplanet.info/PHP/call_OppLCDBQuery.php

You will have the best chance of success working objects with low amplitude and periods that allow covering at least half a cycle every night. Objects with large amplitudes and/or long periods are much more difficult for phase angle studies since, for proper analysis, the data must be reduced to the average magnitude of the asteroid for each night. This reduction requires that you determine the period and the amplitude of the lightcurve; for long period objects that can be difficult. Refer to Harris et al. (1989) for the details of the analysis procedure.

As an aside, some use the maximum light to find the phase slope parameter (G). Even though the results better resemble the behavior of a spherical object of the same albedo, it can produce significantly different values for both H and G versus when using average light, which is the method used for values listed by the Minor Planet Center.

The International Astronomical Union (IAU) has adopted a new system, $H-G_{12}$, introduced by Muinonen et al. (2010). It will be some years before $H-G_{12}$ becomes widely used, but not until a discontinuity flaw in the G_{12} function has been resolved. This discontinuity results in false “clusters” or “holes” in the solution density and makes it impossible to draw accurate conclusions.

We strongly encourage obtaining data as close to 0° as possible, then every $1-2^\circ$ out to 7° , below which the curve tends to be non-linear due to the opposition effect. From 7° out to about 30° , observations at $3-6^\circ$ intervals should be sufficient. Coverage beyond about 50° is not generally helpful since the $H-G$ system is best defined with data from $0-30^\circ$.

It's important to emphasize that all observations should (must) be made using high-quality catalogs to set the comparison star magnitudes. These include ATLAS, Pan-STARRS, SkyMapper, and GAIA2. Catalogs such as CMC-15, APASS, or the MPOSC from *MPO Canopus* should not be used due to significant systematic errors.

Also important is that there are sufficient data from each observing run such that their location can be found on a combined, phased lightcurve derived from two or more nights obtained *near the same phase angle*. This is so that the lightcurve amplitude isn't significantly different. If necessary, the magnitudes for the given run should be adjusted so that they correspond to mid-light of the combined lightcurve. This goes back to the H-G system being based on average, not maximum or minimum light.

For this table, the asteroid magnitudes are brighter than in others. This is because higher precision is required for this work and the asteroid may be a full magnitude or more fainter when it reaches phase angles out to 20-30°.

Num	Name	Date	α	V	Dec	Period	Amp	U
662	Newtonia	01 03.6	0.99	14.5	+20	21.095	0.42-0.51	3-
395	Delia	01 05.0	0.69	14.5	+21	19.71	0.15-0.25	2
566	Stereoskopia	01 06.7	0.93	12.7	+26	12.103	0.03-0.25	3
213	Lilaea	01 12.7	0.53	13.2	+20	12.042	0.07-0.20	3
679	Pax	01 13.1	0.29	11.8	+22	8.452	0.02-0.32	3
515	Athalia	01 14.9	0.14	14.3	+21	10.636	0.13-0.22	3
576	Emanuela	01 18.0	0.13	14.0	+21	20.404	0.06-0.13	2+
135	Hertha	01 18.6	0.86	12.0	+23	8.403	0.12-0.30	3
149	Medusa	01 20.0	0.52	12.5	+19	26.023	0.33-0.56	3
1284	Latvia	01 21.4	0.26	13.0	+20	9.55	0.10-0.23	3-
472	Roma	01 23.9	0.65	11.7	+18	9.800	0.27-0.46	3
33	Polyhymnia	01 28.0	0.65	13.3	+20	18.608	0.13-0.20	3
442	Eichsfeldia	01 28.7	0.50	12.6	+17	11.871	0.24-0.38	3
10	Hygiea	01 28.8	0.73	9.9	+16	27.630	0.09-0.33	3
317	Roxane	01 31.2	0.41	12.7	+16	8.169	0.61-0.75	3
2546	Libitina	02 01.8	0.35	14.3	+18	132.71	0.35	2+
133	Cyrene	02 02.0	0.33	12.1	+18	12.708	0.22-0.26	3
458	Hercynia	02 02.2	0.14	13.1	+17	21.806	0.10-0.48	3
1382	Gerti	02 05.1	0.73	14.5	+18	3.082	0.20-0.36	3
140	Siwa	02 06.5	0.69	12.9	+18	34.445	0.05-0.15	3
3332	Raksha	02 07.4	0.18	14.4	+15	4.806	0.25-0.36	3
431	Nephele	02 10.8	0.29	13.9	+15	13.530	0.03-0.23	3
269	Justitia	02 10.9	0.70	13.6	+12	33.128	0.14-0.25	3
633	Zelima	02 13.2	0.25	14.4	+13	11.730	0.14-0.49	3
834	Burnhamia	02 15.6	0.92	14.3	+10	13.875	0.15-0.22	3
382	Dodona	02 17.1	0.99	12.7	+09	4.113	0.39-0.42	3
1062	Ljuba	02 19.0	0.56	13.7	+13	33.8	0.17-0.18	3
1106	Cydonia	02 19.3	0.41	14.3	+10	2.679	0.10-0.28	3
77	Frigga	02 20.8	0.72	11.9	+13	9.012	0.07-0.20	3
1152	Pawona	02 23.1	0.18	13.7	+10	3.415	0.16-0.26	3
240	Vanadis	02 26.9	0.85	12.5	+11	10.64	0.08-0.34	3
545	Messalina	03 04.8	0.80	13.8	+04	7.2	0.22-0.27	3
1621	Druzhba	03 05.8	0.72	14.2	+04	99.20	0.75-0.75	3
601	Nerthus	03 10.0	0.03	14.3	+04	13.59	0.25-0.29	3
256	Walpurga	03 17.2	0.81	13.7	-01	16.664	0.25-0.58	3
2501	Lohja	03 17.4	0.71	14.0	+03	3.808	0.26-0.45	3
366	Vincentina	03 17.7	0.84	13.2	-01	12.737	0.05	3-
1458	Mineura	03 19.8	0.36	14.6	+00	36.	0.04	1
263	Dresda	03 21.2	0.37	14.4	-01	16.809	0.37-0.55	3
822	Lalage	03 24.4	0.32	14.2	-02	3.345	0.47-0.67	3
1142	Aetolia	03 24.5	0.73	14.4	+01	10.730	0.15-0.22	3-
734	Benda	03 25.2	0.11	14.3	-02	7.110	0.28-0.32	3
321	Florentina	03 26.1	0.77	14.0	+00	2.871	0.31-0.52	3

Shape/Spin Modeling Opportunities

Those doing work for modeling should contact Josef Ďurech at the email address above. If looking to add lightcurves for objects with existing models, visit the Database of Asteroid Models from Inversion Techniques (DAMIT) web site:

<https://astro.troja.mff.cuni.cz/projects/damit/>

Additional lightcurves could lead to the asteroid being added to or improving one in DAMIT, thus increasing the total number of asteroids with spin axis and shape models.

Included in the list below are objects that:

1. Are rated U = 3- or 3 in the LCDB.
2. Do not have reported pole in the LCDB Summary table.
3. Have at least three entries in the Details table of the LCDB where the lightcurve is rated U $\geq$ 2.

The caveat for condition #3 is that no check was made to see if the lightcurves are from the same apparition or if the phase angle bisector longitudes differ significantly from the upcoming apparition. The last check is often not possible because the LCDB does not list the approximate date of observations for all details records. Including that information is an on-going project.

Favorable apparitions are in bold text. NEAs are in italics.

Num	Name	Brightest			LCDB Data		
		Date	Mag	Dec	Period	Amp	U
1015	Christa	01 02.0	13.4	+18	11.23	0.12-0.20	3-
1675	Simonida	01 03.7	13.8	+36	5.289	0.16-0.65	3
1645	Waterfield	01 04.8	15.0	+22	4.861	0.18-0.20	3
395	Delia	01 05.0	14.4	+21	19.681	0.12-0.25	3
289	Nenetta	01 05.2	13.4	+13	6.902	0.18-0.20	3
1186	Turnera	01 08.1	14.5	+36	12.085	0.25-0.34	3
213	Lilaea	01 12.7	13.2	+20	12.042	0.07-0.20	3
811	Nauheima	01 13.0	14.9	+20	4.001	0.11-0.20	3
592	Bathseba	01 13.3	13.4	+9	7.747	0.22-0.32	3
504	Cora	01 15.1	14.0	+25	7.587	0.15-0.27	3
547	Praxedis	01 17.7	13.7	-5	9.105	0.04-0.12	3
109	Felicitas	01 17.8	11.4	+33	13.191	0.06-0.17	3
576	Emanuela	01 18.0	14.0	+21	20.372	0.06-0.14	3
611	Valeria	01 18.3	13.1	+1	6.977	0.08-0.28	3
1330	Spiridonia	01 18.8	14.5	+5	9.67	0.08-0.34	3
593	Titania	01 19.2	12.1	+41	9.897	0.21-0.26	3
273	Atropos	01 19.9	14.5	+0	23.924	0.52-0.65	3
785	Zwetana	01 20.0	12.7	+36	8.888	0.12-0.20	3
1284	Latvia	01 21.4	13.0	+20	9.55	0.10-0.23	3-
472	Roma	01 23.9	11.7	+18	9.801	0.27-0.46	3
28913	2000 OT	01 26.3	14.5	+22	13.754	0.32-0.44	3-
204	Kallisto	01 26.9	13.1	+7	19.489	0.09-0.26	3
1005	Arago	01 27.8	14.5	+36	8.789	0.22-0.25	3
773	Irmintraud	01 28.2	13.4	+24	6.751	0.05-0.17	3
442	Eichsfeldia	01 28.7	12.6	+17	11.871	0.24-0.38	3
1041	Asta	01 29.4	14.5	+36	7.554	0.12-0.14	3-
677	Aaltje	02 02.2	13.6	+9	16.608	0.10-0.37	3
676	Melitta	02 02.2	14.3	+12	16.743	0.04-0.20	3
1262	Sniaudeckia	02 02.3	14.4	+20	17.57	0.06-0.16	3
323	Brucia	02 03.8	13.2	+39	9.463	0.15-0.36	3
1425	Tuorla	02 05.2	14.5	+0	7.75	0.17-0.40	3
1129	Neujmina	02 06.3	14.4	+6	5.084	0.06-0.20	3
3332	Raksha	02 07.4	14.4	+15	4.806	0.25-0.36	3
431	Nephele	02 10.8	13.9	+15	13.53	0.03-0.23	3
269	Justitia	02 11.0	13.6	+12	33.128	0.14-0.25	3
445	Edna	02 12.5	14.4	-3	19.959	0.21-0.27	3
633	Zelima	02 13.2	14.4	+13	11.73	0.14-0.49	3
3754	Kathleen	02 13.9	14.3	+20	11.18	0.13-0.20	3-
414	Liriope	02 15.3	14.5	+20	7.353	0.10-0.14	3-
834	Burnhamia	02 15.9	14.3	+10	13.875	0.15-0.22	3
332	Siri	02 17.7	13.8	+15	8.007	0.10-0.35	3
1062	Ljuba	02 18.9	13.7	+13	33.8	0.17-0.18	3
443	Photographica	02 19.0	12.2	+8	19.795	0.24-0.34	3
1106	Cydonia	02 19.3	14.3	+10	2.679	0.10-0.35	3
299	Thora	02 20.3	14.3	+8	272.9	0.37-0.50	3-
3178	Yoshitsune	02 20.6	13.4	-5	7.478	0.52-0.53	3
465	Alektro	02 22.2	13.5	+7	10.936	0.12-0.18	3
422	Berolina	02 22.2	14.1	+14	25.978	0.06-0.16	3
1567	Alikoski	02 22.8	14.2	+33	16.405	0.08-0.16	3
1152	Pawona	02 23.1	13.7	+10	3.415	0.16-0.26	3
888	Parysatis	02 24.7	13.1	+20	5.931	0.22-0.26	3
68348	2001 LO7	02 25.0	14.1	-1	3.331	0.08-0.30	3
240	Vanadis	02 26.8	12.5	+11	10.64	0.13-0.34	3
70	Panopaea	02 27.2	12.4	+24	15.805	0.07-0.18	3
1164	Kobolda	02 27.3	14.1	+10	4.141	0.21-0.30	3
1375	Alfreda	02 28.0	14.4	+17	19.14	0.17	3-
429	Lotis	02 28.8	13.9	-4	13.577	0.21-0.24	3
545	Messalina	03 04.9	13.8	+4	7.2	0.22-0.27	3
594	Mireille	03 04.9	14.1	+17	4.966	0.18-0.25	3
1085	Amarylilis	03 05.1	14.2	+10	18.111	0.14-0.20	3-
786	Bredichina	03 06.4	13.1	+26	29.434	0.04-0.60	3-

Num	Name	Brightest			LCDB Data			U
		Date	Mag	Dec	Period	Amp		
2375	Radek	03 08.2	14.3	+24	16.875	0.17-0.20	3	
1296	Andree	03 08.6	14.2	-1	5.184	0.23-0.27	3	
86	Semele	03 09.7	13.6	+10	16.634	0.13-0.18	3	
374	Burgundia	03 10.4	12.5	-6	6.962	0.07-0.33	3	
498	Tokio	03 15.1	13.6	+15	41.85	0.08-0.36	3	
559	Nanon	03 17.0	13.1	+14	10.059	0.07-0.26	3	
1305	Pongola	03 19.1	14.3	+4	8.335	0.14-0.19	3-	
715	Transvaalia	03 20.7	14.4	+14	11.83	0.14-0.32	3	
862	Franzia	03 24.5	14.1	-19	7.523	0.07-0.13	3	
1142	Aetolia	03 24.6	14.4	+1	10.73	0.15-0.22	3-	
734	Benda	03 25.1	14.3	-2	7.11	0.25-0.32	3	
583	Klotilde	03 25.2	13.0	-13	9.213	0.17-0.30	3	
1259	Ogyalla	03 25.2	14.3	+1	17.334	0.25-0.41	3	
542	Susanna	03 25.6	14.1	+7	10.069	0.11-0.30	3	
752	Sulamitis	03 28.9	13.4	+6	27.367	0.20-0.45	3	

Radar-Optical Opportunities

Past radar targets:

<http://echo.jpl.nasa.gov/~lance/radar.nea.periods.html>

Arecibo targets:

<http://www.naic.edu/~pradar>

<http://www.naic.edu/~pradar/ephemfuture.txt>

Goldstone targets:

http://echo.jpl.nasa.gov/asteroids/goldstone_asteroid_schedule.html

These are based on *known* targets at the time the list was prepared. It is very common for newly discovered objects to move up the list and become radar targets on short notice. We recommend that you keep up with the latest discoveries the Minor Planet Center observing tools.

In particular, monitor NEAs and be flexible with your observing program. In some cases, you may have only 1-3 days when the asteroid is within reach of your equipment. Be sure to keep in touch with the radar team (through Benner's email or their Facebook or Twitter accounts) if you get data. The team may not always be observing the target but your initial results may change their plans. In all cases, your efforts are greatly appreciated.

Use the ephemerides below as a guide to your best chances for observing, but remember that photometry may be possible before and/or after the ephemerides given below. Note that *geocentric* positions are given. Use these web sites to generate updated and *topocentric* positions:

MPC: <http://www.minorplanetcenter.net/iau/MPEph/MPEph.html>
JPL: <http://ssd.jpl.nasa.gov/?horizons>

In the ephemerides below, ED and SD are, respectively, the Earth and Sun distances (AU), V is the estimated Johnson V magnitude, and α is the phase angle. SE and ME are the great circle distances (in degrees) of the Sun and Moon from the asteroid. MP is the lunar phase and GB is the galactic latitude. "PHA" indicates that the object is a "potentially hazardous asteroid", meaning that at some (long distant) time, its orbit might take it very close to Earth.

About YORP Acceleration

Many, if not all, of the targets in this section are near-Earth asteroids. These objects are particularly sensitive to YORP acceleration. YORP (Yarkovsky-O'Keefe-Radzievskii-Paddack) is the asymmetric thermal re-radiation of sunlight that can cause an asteroid's rotation period to increase or decrease. High precision lightcurves at multiple apparitions can be used to model the asteroid's *sidereal* rotation period and see if it's changing.

It usually takes four apparitions to have sufficient data to determine if the asteroid rotation rate is changing under the influence of YORP. This is why observing an asteroid that already has a well-known period remains a valuable use of telescope time. It is even more so when considering the BYORP (binary-YORP) effect among binary asteroids that has stabilized the spin so that acceleration of the primary body is not the same as if it would be if there were no satellite.

To help focus efforts in YORP detection, Table I gives a quick summary of this quarter's radar-optical targets. The family or group for the asteroid is given under the number name. Also under the name will be additional flags such as "PHA" for Potentially Hazardous Asteroid, NPAR for a tumbler, and/or "BIN" to indicate the asteroid is a binary (or multiple) system. "BIN?" means that the asteroid is a suspected but not confirmed binary. The period is in hours and, in the case of binary, for the primary. The Amp column gives the known range of lightcurve amplitudes. The App columns gives the number of different apparitions at which a lightcurve period was reported while the Last column gives the year for the last reported period. The R SNR column indicates the estimated radar SNR using the tool at:

<http://www.naic.edu/~eriverav/scripts/index.php>

The SNRs were calculated using the current MPCORB absolute magnitude (H), a period of 4 hours (2 hours if $D \leq 200$ m) if it's not known, and the approximate minimum Earth distance during the current quarter. These are estimates only and assume that the radars are fully functional.

If the row is in bold text, the object was found on the radar planning pages listed above. Otherwise, the planning tool at:

http://www.minorplanet.info/PHP/call_OppLCDBQuery.php

was used to find known NEAs that were $V < 18.0$ during the quarter.

It's rarely the case, especially for shape/spin axis modeling, that there are too many observations. Remember that the best set for modeling includes data not just from multiple apparitions but from as wide a range of phase angles during each apparition as well.

Asteroid	Period	Amp	App	Last	R SNR
2003 AF23	-	-	-	-	25 G
NEA PHA					
2016 CO247	-	-	-	-	40
NEA PHA					
(332446)	-	-	-	-	1000 G
NEA					MAINT
2015 NU13	-	-	-	-	220 G
NEA PHA					MAINT
(189040) 2000 MU1	-	-	-	-	5 G
(65717) 1993 BX3	20.46	0.91	1	1995	95 G
NEA					
(363024) 1998 OK1	-	-	-	-	20 G
NEA					
(468727) 2919 JE87	-	-	-	-	85 G
NEA					
2016 CL136	-	-	-	-	60 G
NEA PHA					
(456537) 2007 BG	-	-	-	-	45 G
NEA					
(311554) 2006 BQ147	9.15	0.31	1	2015	21 G
NEA					

Asteroid	Period	Amp	App	Last	R SNR
(85953) 1999 FK21 NEA	68.44	0.45 0.87	4	2018	15 G
(99942) Apophis NEA PHA	30.56	0.3 1.14	2	2013	13 G
(535844) 2915 BY310 NEA	-	-	-	-	45 G
(138127) 2000 EE14 NEA	2.586	0.2 0.26	1	2014	3 G
(462552) 2009 CB3 NEA	-	-	-	-	15 G
(351545) 1004 TE15 NEA	-	-	-	-	20 G
162173 Ryugu NEA	7.627	0.1 0.16	3	2020	60 G
(271480) 2004 FX31 NEA	-	-	-	-	25 G
(231937) 2001 FO32 NEA	-	-	-	-	3200 G
(514596) 2003 FG NEA	8.692	1.4	1	2003	35 G

Table I. Summary of radar-optical opportunities for the current quarter. Period and amplitude data are from the asteroid lightcurve database (LCDB; Warner et al., 2009a). SNR values are *estimates* that are affected by radar power output along with rotation period, size, and distance. They are given for relative comparisons among the objects in the list.

The “A” is for Arecibo; “G” is for Goldstone. Due to the severe damage at Arecibo in mid-2020, no SNR estimates were made for that facility. “MAINT” means that the asteroid is not scheduled because of planned maintenance. Photometric observations should still be made in case the situation at Goldstone changes.

2003 AF23 (H = 20.90, PHA)

No rotation periods are listed in the LCDB (Warner et al., 2009a). The estimated diameter is 4.4 km. The observing window is short so, with luck, the rotation period won’t be too long.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/30	13 34.0	+32 49	0.06	0.99	17.9	85.0	91	89	+1.00	+79
01/01	12 24.6	+33 59	0.05	1.00	17.0	70.3	107	53	-0.96	+81
01/03	10 50.9	+31 39	0.05	1.01	16.2	50.5	127	18	-0.84	+63
01/05	09 16.1	+24 31	0.05	1.03	15.6	29.0	150	42	-0.65	+42
01/07	08 05.0	+15 51	0.06	1.04	15.5	13.4	166	85	-0.43	+23
01/09	07 18.4	+08 52	0.07	1.05	15.9	12.4	167	123	-0.22	+10

2016 CO247 (H = 20.50, PHA)

The estimated diameter for this NEA is 230 meters. This should be large enough so that the period won’t be super-fast ($P < 2$ h). However, it’s a good plan to assume that short exposures are required to avoid *rotational smearing* (Pravec et al., 2000). The rapid sky motion makes short exposures even more important.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	15 48.3	+29 23	0.07	0.96	18.7	108.5	68	96	-0.96	+51
01/03	14 46.6	+32 18	0.06	0.98	17.7	95.7	81	63	-0.84	+65
01/05	13 16.8	+33 02	0.05	0.99	16.7	77.6	99	33	-0.65	+82
01/07	11 35.2	+28 57	0.05	1.01	16.1	56.4	121	45	-0.43	+73
01/09	10 13.4	+21 38	0.06	1.03	15.8	37.9	140	85	-0.22	+54
01/11	09 19.3	+14 50	0.07	1.04	15.9	25.2	153	124	-0.06	+39
01/13	08 44.4	+09 49	0.08	1.06	16.2	18.2	160	157	+0.00	+30
01/15	08 21.1	+06 17	0.10	1.08	16.5	15.5	163	159	+0.04	+23
01/17	08 04.7	+03 47	0.12	1.10	16.9	15.4	163	134	+0.16	+18
01/19	07 52.8	+01 59	0.14	1.11	17.3	16.4	161	108	+0.33	+15
01/21	07 43.9	+00 40	0.16	1.13	17.6	17.8	159	84	+0.52	+12

(332446) 2008 AF4 (H = 19.65, PHA)

The only information in the LCDB is from Binzel et al. (2019), who determined this to be a type S/Sr type asteroid. The estimated diameter is 350 meters.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/05	14 41.3	-36 28	0.03	0.97	16.7	121.0	58	57	-0.65	+21
01/08	12 37.5	-05 28	0.03	0.99	14.5	81.6	97	29	-0.32	+57
01/11	11 18.9	+18 43	0.04	1.01	14.3	51.9	126	99	-0.06	+67
01/14	10 33.8	+29 41	0.05	1.02	14.8	37.5	141	151	+0.01	+60
01/17	10 06.0	+34 54	0.07	1.04	15.2	29.9	148	152	+0.16	+54
01/20	09 47.5	+37 42	0.09	1.06	15.7	25.5	152	115	+0.42	+50
01/23	09 34.2	+39 19	0.11	1.08	16.0	22.9	155	79	+0.70	+48
01/26	09 24.2	+40 17	0.13	1.10	16.4	21.4	156	43	+0.92	+46
01/29	09 16.5	+40 51	0.15	1.12	16.8	20.7	156	20	-1.00	+44
02/01	09 10.4	+41 08	0.17	1.14	17.1	20.7	156	48	-0.88	+43
02/04	09 05.6	+41 13	0.19	1.16	17.4	21.0	155	88	-0.58	+42
02/07	09 01.7	+41 10	0.21	1.18	17.7	21.6	154	128	-0.25	+41
02/10	08 58.8	+40 59	0.23	1.20	18.0	22.4	152	160	-0.04	+41

2015 NU13 (H = 19.50, PHA)

This NEA has an estimated diameter of 370 meters. There are no entries in the LCDB. Unfortunately, the asteroid stays close to the galactic plane and so rich star fields may hamper data reduction.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/15	08 14.2	-11 32	0.06	1.04	14.9	31.5	147	144	+0.04	+13
01/17	08 13.8	-03 23	0.08	1.05	15.1	22.9	155	134	+0.16	+17
01/19	08 13.4	+02 07	0.09	1.07	15.4	16.9	162	114	+0.33	+19
01/21	08 13.2	+06 00	0.11	1.09	15.6	12.6	166	91	+0.52	+21
01/23	08 13.0	+08 53	0.13	1.11	15.9	9.6	169	67	+0.70	+22
01/25	08 12.9	+11 06	0.14	1.13	16.1	7.7	171	43	+0.86	+23
01/27	08 12.9	+12 50	0.16	1.15	16.4	7.1	172	19	+0.96	+24
01/29	08 12.9	+14 14	0.18	1.16	16.7	7.4	171	14	-1.00	+24
01/31	08 13.0	+15 22	0.20	1.18	17.0	8.3	170	38	-0.94	+25
02/02	08 13.2	+16 19	0.22	1.20	17.2	9.6	168	66	-0.79	+25
02/04	08 13.4	+17 07	0.24	1.22	17.5	11.0	166	94	-0.58	+26

(189040) 2000 MU1 (H = 19.90)

Binzel et al. (2019) determined this to be a type S asteroid. The estimated diameter is 310 meters. Be wary of the large solar phase angles. These can lead to lightcurve shapes and amplitudes that defy easy period analysis.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/05	09 41.8	-12 03	0.20	1.12	18.3	43.9	128	38	-0.65	+30
01/08	09 58.7	-12 38	0.18	1.10	18.1	45.5	127	66	-0.32	+32
01/11	10 19.7	-13 07	0.16	1.08	17.8	47.7	126	99	-0.06	+35
01/14	10 46.4	-13 28	0.14	1.06	17.6	50.8	123	131	+0.01	+39
01/17	11 20.9	-13 30	0.12	1.05	17.4	55.3	119	155	+0.16	+44
01/20	12 05.0	-13 00	0.10	1.03	17.3	61.6	113	159	+0.42	+48
01/23	12 59.2	-11 38	0.10	1.01	17.3	70.0	105	141	+0.70	+51
01/26	14 00.4	-09 14	0.09	1.00	17.5	80.0	95	118	+0.92	+50
01/29	15 01.2	-06 09	0.09	0.98	17.9	90.1	84	92	-1.00	+44

(65717) 1993 BX3 (H = 20.80)

Mottola et al. (1995) reported a period of 20.463 h. This would suggest that a collaboration involving two or more observations at well-separated longitudes would make it easier to find the period this time around. The estimated diameter is only 200 m, so the long period makes this NEA a bit on the unusual side.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	04 10.1	-36 38	0.06	1.00	17.0	66.9	110	84	-0.96	-47
01/11	05 49.4	-41 14	0.05	1.00	16.5	64.6	113	115	-0.06	-29
01/21	07 55.2	-37 00	0.05	1.01	16.2	54.8	123	93	+0.52	-5
01/31	09 26.8	-25 18	0.06	1.03	16.2	41.3	137	43	-0.94	+18
02/10	10 15.4	-13 52	0.07	1.05	16.4	28.1	150	131	-0.04	+34
02/20	10 39.7	-05 13	0.09	1.08	16.6	16.0	162	99	+0.52	+45
03/02	10 52.4	+00 47	0.12	1.11	16.9	5.8	173	35	-0.90	+51
03/12	10 59.8	+04 42	0.15	1.15	17.5	6.2	173	169	-0.02	+55
03/22	11 05.9	+07 01	0.20	1.19	18.4	13.8	163	69	+0.54	+58
04/01	11 12.7	+08 05	0.25	1.23	19.2	20.4	155	70	-0.85	+60

(363024) 1998 OK1 (H = 19.32, PHA)

Mainzer et al. (2016) used WISE observations to find a diameter of 560 meters and albedo of 0.099 when using $H = 19.4$. This is darker than many NEAs. The LCDB shows 70 NEAs with $p_V \leq 0.10$. On the other hand, there are 3429 objects in the LCDB with $0.18 \leq p_V \leq 0.25$.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/20	23 32.4	+19 43	0.08	0.95	17.9	111.9	64	31	+0.42	-39
01/23	00 11.7	+38 20	0.07	0.97	17.1	96.5	79	49	+0.70	-24
01/26	01 10.4	+54 18	0.08	0.99	16.7	81.5	94	62	+0.92	-8
01/29	02 33.6	+64 19	0.10	1.01	16.7	69.9	105	74	-1.00	+4
02/01	04 09.6	+68 24	0.11	1.03	16.9	61.6	113	92	-0.88	+12
02/04	05 31.2	+68 38	0.14	1.06	17.1	55.9	118	114	-0.58	+18
02/07	06 28.1	+67 12	0.16	1.08	17.4	51.7	121	134	-0.25	+23
02/10	07 06.0	+65 17	0.18	1.10	17.6	48.7	123	137	-0.04	+26
02/13	07 32.1	+63 20	0.21	1.12	17.9	46.4	125	119	+0.02	+29

(468727) 2010 JE87 (H = 20.70, PHA)

Mainzer et al. (2016) reported $D = 0.308 \pm 0.016$ km, $p_V = 0.108 \pm 0.027$ when using $H = 20.60$. There is no rotation period given in the LCDB. This one is decidedly for Northern observers.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/28	16 23.1	+54 52	0.04	0.99	16.9	86.1	91	88	+0.99	+43
01/29	15 48.2	+62 49	0.05	0.99	16.9	78.1	99	76	-1.00	+44
01/30	15 02.5	+68 42	0.05	1.00	16.9	71.6	105	69	-0.98	+44
01/31	14 05.5	+72 36	0.06	1.01	17.0	66.5	110	66	-0.94	+43
02/01	13 01.4	+74 42	0.07	1.01	17.1	62.4	114	68	-0.88	+42
02/02	11 59.2	+75 23	0.07	1.02	17.2	59.3	117	74	-0.79	+41
02/03	11 06.6	+75 07	0.08	1.03	17.4	56.7	119	82	-0.69	+40
02/04	10 25.6	+74 20	0.09	1.03	17.5	54.7	121	92	-0.58	+39
02/05	09 54.7	+73 19	0.10	1.04	17.7	53.1	122	102	-0.47	+38
02/06	09 31.3	+72 14	0.10	1.05	17.8	51.8	123	112	-0.36	+38
02/07	09 13.5	+71 09	0.11	1.05	17.9	50.7	124	121	-0.25	+37

2016 CL136 (H = 21.40, PHA)

Masiero et al. (2016) used WISE data to find a diameter of 0.123 ± 0.057 km and albedo of 0.316 ± 0.3599 . Some 3-4 color photometry and H-G observations might narrow down the taxonomic class and so, within limits, narrow the range of albedos.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/30	14 59.0	+24 17	0.05	0.99	17.6	82.1	95	70	-0.98	+61
01/31	14 12.7	+28 22	0.04	1.00	16.9	70.7	107	49	-0.94	+72
02/01	13 08.8	+32 03	0.04	1.01	16.3	56.3	122	32	-0.88	+84
02/02	11 50.4	+33 37	0.04	1.01	15.7	39.8	139	34	-0.79	+75
02/03	10 32.6	+32 06	0.04	1.02	15.4	24.0	155	55	-0.69	+60
02/04	09 30.0	+28 34	0.04	1.03	15.3	12.5	167	80	-0.58	+46
02/05	08 45.0	+24 40	0.05	1.03	15.5	10.5	169	102	-0.47	+35
02/06	08 13.4	+21 14	0.06	1.04	16.1	15.5	164	123	-0.36	+27
02/07	07 50.8	+18 26	0.06	1.05	16.5	20.8	158	142	-0.25	+21
02/08	07 34.2	+16 12	0.07	1.05	17.0	25.2	153	158	-0.16	+17
02/09	07 21.7	+14 24	0.08	1.06	17.4	28.8	149	169	-0.09	+13
02/10	07 12.0	+12 58	0.09	1.06	17.7	31.7	145	163	-0.04	+10

(456537) 2007 BG (H = 19.50)

The diameter for this NEA is given by Mainzer et al. (2016) to be 0.308 ± 0.108 km; they list an albedo of 0.242 ± 0.186 based on using $H = 19.5$. The size should make it less likely that the asteroid is super-fast rotator. The geometry of the approach has the asteroid getting out of the galactic plane just as the solar elongation is decreasing below 90° .

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/25	10 46.6	-51 10	0.18	1.04	18.2	66.7	104	103	+0.86	+7
01/28	10 39.7	-52 58	0.17	1.04	18.0	66.8	104	84	+0.99	+5
01/31	10 30.3	-54 56	0.15	1.03	17.8	67.1	105	68	-0.94	+3
02/03	10 17.3	-57 07	0.14	1.03	17.6	67.8	105	64	-0.69	+0
02/06	09 58.8	-59 32	0.12	1.02	17.4	69.0	104	74	-0.36	-4
02/09	09 31.5	-62 08	0.11	1.02	17.2	70.8	103	88	-0.09	-8
02/12	08 49.7	-64 43	0.10	1.01	17.0	73.7	101	97	+0.00	-13
02/15	07 45.3	-66 38	0.08	1.00	16.8	78.1	97	95	+0.11	-20
02/18	06 14.3	-66 18	0.07	0.99	16.8	84.4	91	88	+0.34	-28
02/21	04 35.5	-61 25	0.06	0.98	16.8	93.4	83	84	+0.62	-40

(311554) 2006 BQ147 (H = 18.70)

Stephens (2015) reported a period of 9.15 h for this 540-meter NEA. The lightcurve amplitude was 0.31 mag at a solar phase angle of 48° . Considering that alone, the amplitude of the lightcurve this apparition could be even larger. However, the phase angle bisector longitude, λ_{PAB} , will be nearly 100° different. This could mean an entirely different view of the asteroid, e.g., pole-on instead of equatorial.

Since the λ_{PAB} will change dramatically during the apparition, shape/spin axis modeling would benefit greatly by getting 2-4 separate lightcurves over the entire interval of the ephemeris and so reveal any changes in the lightcurve shape and/or amplitude.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/28	12 23.4	-17 17	0.26	1.12	18.0	52.8	115	75	+0.99	+45
01/31	12 31.6	-15 32	0.23	1.11	17.7	52.1	117	38	-0.94	+47
02/03	12 41.0	-13 13	0.21	1.10	17.4	51.4	119	14	-0.69	+50
02/06	12 52.2	-10 05	0.18	1.09	17.1	50.7	121	48	-0.36	+53
02/09	13 05.9	-05 46	0.16	1.08	16.7	50.2	123	88	-0.09	+57
02/12	13 23.4	+00 13	0.13	1.07	16.3	50.4	124	127	+0.00	+62
02/15	13 46.8	+08 35	0.11	1.05	16.0	52.1	123	158	+0.11	+67
02/18	14 19.7	+19 52	0.10	1.04	15.8	56.6	119	148	+0.34	+69
02/21	15 07.8	+33 28	0.09	1.02	15.8	65.0	110	118	+0.62	+60
02/24	16 17.6	+46 18	0.09	1.01	16.2	76.1	99	95	+0.87	+45
02/27	17 47.3	+54 27	0.10	0.99	16.8	86.8	87	89	+1.00	+31
03/02	19 16.0	+57 00	0.12	0.97	17.4	95.5	78	93	-0.90	+19
03/05	20 24.1	+56 09	0.14	0.95	18.0	102.0	70	94	-0.62	+11

(85953) 1999 FK21 (H = 18.10)

Several rotation periods are reported in the LCDB. Skiff (2011) found a period of 28.1 h. Warner (2018), however, found a period of 68.44 h with lightcurve amplitude of 0.87 mag based on observations in 2018 April. The data could not be fit to a period near 28 h. Pravec et al. (2019) reported a period of 27.88 h using data from 2014 and a period of 28.08 using data from 2018.

This calls for a coordinated campaign of observers at well-separated longitudes. Using one of the high-quality catalogs for comp star magnitudes will be important in this case.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/18	04 21.8	-43 00	0.14	0.99	16.9	86.9	85	60	+0.34	-45
02/20	04 54.7	-35 40	0.15	1.00	16.7	79.8	92	57	+0.52	-38
02/22	05 19.6	-28 39	0.16	1.02	16.7	73.7	98	54	+0.71	-32
02/24	05 38.7	-22 20	0.17	1.04	16.7	68.6	102	56	+0.87	-25
02/26	05 53.8	-16 51	0.18	1.05	16.8	64.7	106	65	+0.98	-20
02/28	06 06.1	-12 10	0.20	1.07	16.9	61.6	108	82	-0.99	-15
03/02	06 16.3	-08 12	0.22	1.08	17.1	59.3	110	103	-0.90	-12
03/04	06 24.9	-04 50	0.24	1.10	17.3	57.6	111	125	-0.73	-8
03/06	06 32.4	-01 58	0.26	1.11	17.4	56.3	111	146	-0.51	-5
03/08	06 39.1	+00 29	0.28	1.12	17.6	55.3	111	155	-0.29	-3
03/10	06 45.0	+02 35	0.30	1.14	17.8	54.6	111	144	-0.12	+0
03/12	06 50.5	+04 25	0.32	1.15	17.9	54.0	111	124	-0.02	+2
03/14	06 55.5	+06 00	0.34	1.16	18.1	53.7	110	102	+0.01	+4

99942 Apophis (H = 18.90, PHA)

This approximately 400-m NEA will be the subject of many campaigns during this year's approach in order to characterize it in as much detail as possible and refine its orbit. All this is in anticipation of the extremely close flyby in 2029 April. There are three reported periods in the LCDB, all near 30.55 h: Behrend (2005), Oey (2014), and Pravec et al. (2014).

The asteroid will be available for several weeks. Given the long period, a coordinated campaign of observers is recommended.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	11 40.3	-14 00	0.24	1.05	18.3	68.0	99	61	-0.96	+45
01/11	11 44.1	-16 18	0.22	1.07	17.9	61.9	107	79	-0.06	+44
01/21	11 41.9	-18 14	0.19	1.08	17.5	54.9	116	144	+0.52	+42
01/31	11 31.0	-19 25	0.17	1.09	16.9	46.4	127	34	-0.94	+40
02/10	11 07.8	-19 13	0.14	1.10	16.3	35.9	139	119	-0.04	+37
02/20	10 30.7	-16 31	0.12	1.10	15.7	24.9	152	101	+0.52	+35
03/02	09 45.0	-10 41	0.11	1.10	15.4	21.9	156	52	-0.90	+31
03/12	09 02.1	-02 49	0.11	1.09	15.8	33.4	143	151	-0.02	+27
03/22	08 31.2	+04 49	0.12	1.07	16.3	48.3	126	36	+0.54	+24
04/01	08 13.1	+10 59	0.14	1.06	16.9	61.5	112	113	-0.85	+23
04/11	08 04.1	+15 48	0.15	1.04	17.4	73.0	99	110	-0.01	+23

(535844) 2015 BY310 (H = 21.70, PHA)

Pravec et al. (2019) reported a period of 0.0926702 h (5.56 min) for this 140-m NEA. Based on Pravec et al. (2000), exposures should be no more than about 60 sec to avoid *rotational smearing*. This is when a single exposure covers too much a full rotation and so details about the shape and amplitude are reduced or even lost.

The observing window is fairly short and hampered by close proximity to a nearly full moon and low galactic longitudes. The larger the telescope, the better the chances for success in this case.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/20	07 39.5	+21 55	0.09	1.06	17.9	35.4	142	49	+0.52	+20
02/22	07 30.8	+19 55	0.08	1.05	17.8	39.2	138	24	+0.71	+17
02/24	07 21.1	+17 26	0.07	1.04	17.7	43.3	134	9	+0.87	+14
02/26	07 09.8	+14 21	0.06	1.03	17.6	48.0	129	35	+0.98	+11
02/28	06 56.7	+10 27	0.06	1.02	17.5	53.3	124	66	-0.99	+6
03/02	06 41.1	+05 31	0.05	1.02	17.4	59.5	118	98	-0.90	+0
03/04	06 22.1	-00 42	0.05	1.01	17.3	66.9	111	127	-0.73	-7
03/06	05 58.6	-08 25	0.04	1.00	17.4	75.6	102	145	-0.51	-15
03/08	05 29.4	-17 32	0.04	0.99	17.6	85.5	92	133	-0.29	-26

(138127) 2000 EE14 (H = 17.01)

Warner (2014) found a period of 2.586 h. Vaduvescu et al. (2017) found a similar period of 2.5904 h. The period and size of 1.2 km make this a good candidate for being a binary asteroid.

Don't give up it too soon. It's not uncommon for observations over a few consecutive nights to show no signs of a satellite (deviations in the main lightcurve) only to be followed by a period of several days that reveals mutual events (occultations/eclipses) due to the satellite.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/21	15 49.7	-36 13	0.37	0.85	18.1	98.9	59	144	+0.52	+14
01/31	15 54.3	-29 19	0.32	0.92	17.6	92.5	69	84	-0.94	+19
02/10	16 06.3	-19 34	0.26	0.97	17.1	86.9	78	56	-0.04	+24
02/20	16 24.7	-04 30	0.21	1.00	16.4	81.7	86	164	+0.52	+30
03/02	16 51.5	+18 40	0.17	1.01	15.9	77.9	92	58	-0.90	+35
03/12	17 34.6	+46 23	0.17	1.01	16.0	78.8	91	90	-0.02	+32
03/22	18 59.4	+67 20	0.21	1.00	16.5	83.7	84	87	+0.54	+24
04/01	21 50.7	+75 53	0.26	0.97	17.2	89.5	75	108	-0.85	+17

(462550) 2009 CB3 (H = 19.51)

No rotation periods were found in the LCDB. The estimated diameter is 370 m, so it's unlikely, but not impossible, that the rotation period is less than 2 h. The large phase angles may lead to unusually-shaped lightcurves.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/05	03 56.4	+26 08	0.08	0.98	17.4	97.4	78	173	-0.62	-21
03/06	04 39.7	+30 42	0.08	0.99	17.2	87.8	87	171	-0.51	-11
03/07	05 19.4	+33 49	0.09	1.00	17.1	79.8	95	168	-0.39	-2
03/08	05 54.1	+35 45	0.10	1.02	17.1	73.2	101	163	-0.29	+5
03/09	06 23.4	+36 51	0.11	1.03	17.2	67.9	106	157	-0.20	+11
03/10	06 47.7	+37 24	0.13	1.04	17.3	63.7	110	149	-0.12	+15
03/11	07 07.9	+37 36	0.14	1.05	17.5	60.4	113	141	-0.06	+19
03/12	07 24.7	+37 37	0.15	1.07	17.6	57.6	115	132	-0.02	+22
03/13	07 38.8	+37 30	0.17	1.08	17.8	55.4	117	123	+0.00	+25
03/14	07 50.7	+37 19	0.18	1.09	17.9	53.6	118	113	+0.01	+27
03/15	08 00.9	+37 05	0.19	1.10	18.1	52.1	119	103	+0.03	+29

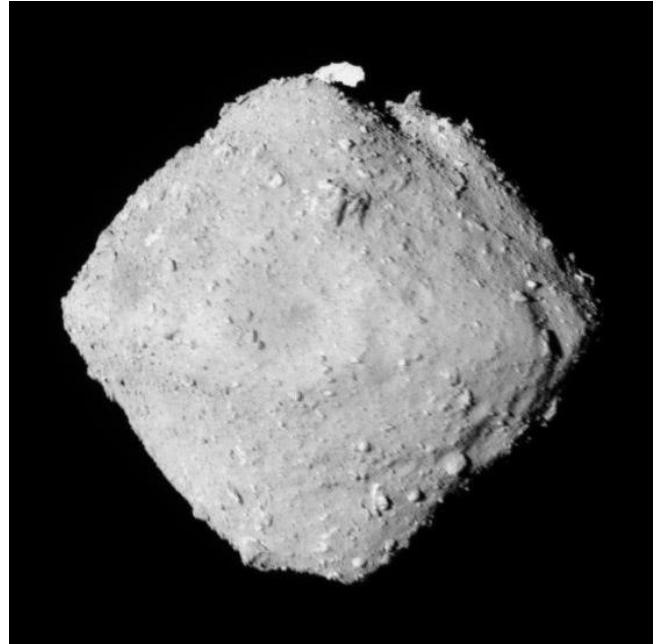
(351545) 2005 TE15 (H = 19.70)

Based on the LCDB, the rotation period for this NEA is unknown. The estimated diameter is 340 m.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/25	12 16.9	+58 53	0.19	1.11	18.0	45.8	127	53	+0.93	+58
02/27	12 14.2	+60 43	0.17	1.10	17.9	47.7	125	50	+1.00	+56
03/01	12 10.2	+62 45	0.16	1.09	17.8	49.9	123	60	-0.96	+54
03/03	12 04.6	+65 00	0.15	1.08	17.7	52.4	121	77	-0.82	+51
03/05	11 56.4	+67 30	0.14	1.06	17.6	55.4	118	97	-0.62	+49
03/07	11 44.1	+70 18	0.13	1.05	17.5	58.8	115	114	-0.39	+46
03/09	11 24.4	+73 25	0.12	1.04	17.4	62.7	111	123	-0.20	+42
03/11	10 49.4	+76 50	0.11	1.03	17.3	67.4	107	121	-0.06	+38
03/13	09 38.9	+80 11	0.10	1.02	17.3	72.9	102	108	+0.00	+33
03/15	07 15.5	+81 55	0.09	1.01	17.3	79.4	96	90	+0.03	+28
03/17	04 35.4	+79 19	0.08	1.00	17.3	87.1	88	70	+0.12	+21

162173 Ryugu (H = 19.22, PHA)

Ryugu has an equatorial diameter of about 1 km. Its pole-to-pole diameter is about 870 m (Watanabe et al., 2019). The Hayabusa2 spacecraft launched by Japan reached the asteroid on 2018 June. The close-up images showed the shape to be a "spinning top", i.e., mostly spherical but with an equatorial bulge that is believed to be caused by material trying to escape from the asteroid due to centrifugal force but, after failing to do so, settles down near the equator.



Credit: JAXA Hayabusa2.

After obtaining surface samples, the spacecraft started its return journey to Earth in 2019 November. As of this writing (2020 October), the spacecraft should complete its homeward trip sometime in 2020 December.

There are several reports of a period of about 7.63 h in the LCDB, e.g., Abe (2008) and Müller et al. (2011), which are from Earth-based observations. Most accurate is that from Watanabe et al. (2019), who used space craft observations to find a period of 7.63262 h. On the other hand, Warner and Stephens (2021) found a period of 7.404 h and could not make the data fit the slightly longer period nor explain the significant difference.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/10	09 14.7	-70 28	0.10	1.00	17.0	79.1	95	85	-0.04	-15
02/20	09 54.3	-64 28	0.11	1.02	17.0	69.4	104	106	+0.52	-8
03/02	10 16.2	-57 52	0.12	1.05	16.9	59.4	114	65	-0.90	-1
03/12	10 30.4	-50 26	0.13	1.08	16.9	49.4	125	115	-0.02	+6
03/22	10 42.2	-42 14	0.15	1.11	16.9	40.1	134	90	+0.54	+15
04/01	10 54.3	-33 58	0.17	1.14	17.0	33.3	141	64	-0.85	+23
04/11	11 07.3	-26 27	0.20	1.17	17.3	30.3	144	145	-0.01	+31

(271480) 2004 FX31 (H = 17.52)

Mainzer et al. (2016) found $D = 0.709 \pm 0.223$ km and $p_V = 0.352 \pm 0.222$ when using $H = 17.5$. The albedo seems high for an NEA. Reducing it by one-half sigma, to about 0.2, would make the value more typical and the estimated diameter would then be about 930 m. Here is another case where 3-4 color photometry and finding the H-G parameters *might* help get a better idea of the taxonomic class and, based on averages for a given taxonomic class, refine the adopted albedo value.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/20	17 47.8	+37 14	0.13	1.01	15.9	80.8	92	119	+0.35	+28
03/22	17 24.2	+41 00	0.14	1.02	15.9	75.0	97	112	+0.54	+33
03/24	17 02.7	+43 50	0.15	1.04	16.0	70.2	101	99	+0.73	+38
03/26	16 43.3	+45 56	0.17	1.05	16.1	66.2	105	84	+0.90	+41
03/28	16 25.8	+47 29	0.18	1.07	16.2	62.9	108	71	+0.99	+44
03/30	16 10.0	+48 38	0.20	1.08	16.4	60.1	110	64	-0.98	+46
04/01	15 55.7	+49 28	0.22	1.10	16.5	57.7	112	68	-0.85	+48
04/03	15 42.8	+50 02	0.23	1.11	16.6	55.6	113	79	-0.66	+50
04/05	15 31.1	+50 25	0.25	1.13	16.8	53.8	114	93	-0.43	+52
04/07	15 20.5	+50 38	0.27	1.14	16.9	52.3	115	107	-0.24	+53
04/09	15 10.8	+50 44	0.29	1.16	17.0	50.9	116	117	-0.09	+55

(231937) 2001 FO32 (H = 17.70, PHA)

Binzel et al. (2019) found this to be a type S/Sr asteroid. Using a default albedo of 0.2 for the S complex, the estimated diameter is 860 m. There is no rotation period listed in the LCDB.

Note that the ephemeris is split into two blocks. The first covers March while the second reaches into May, after the asteroid comes out of conjunction with the Sun.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/01	12 58.2	-31 35	0.42	1.30	17.8	35.9	130	36	-0.96	+31
03/06	13 02.4	-32 19	0.31	1.23	17.1	36.3	133	52	-0.51	+30
03/11	13 08.6	-33 13	0.21	1.16	16.2	37.0	136	109	-0.06	+30
03/16	13 23.3	-34 51	0.11	1.08	14.7	39.4	136	151	+0.06	+28
03/21	16 40.6	-41 30	0.02	1.00	11.7	73.8	105	160	+0.44	+3
03/26	00 19.5	+27 11	0.09	0.92	21.2	152.6	25	126	+0.90	-35

04/30	01 18.7	+20 51	0.95	0.31	18.3	92.2	18	125	-0.88	-42
05/05	01 44.4	+17 30	1.12	0.30	17.5	61.8	15	62	-0.38	-44
05/10	02 15.4	+14 35	1.26	0.36	17.5	39.0	13	8	-0.03	-44
05/15	02 46.0	+12 19	1.38	0.44	17.9	27.9	12	47	+0.09	-42
05/20	03 13.9	+10 33	1.48	0.54	18.3	23.6	12	103	+0.52	-39

(514596) 2003 FG (H = 19.60)

Pravec et al. (2005) reported the rotation period to be 8.692 h with no obvious signs of tumbling. Given the size and rotation period, this 360-m NEA would be a good candidate for tumbling (Pravec et al., 2005; 2014). Accurately-calibrated data will be necessary to confirm whether or not the asteroid might be in a low-level of tumbling.

The period being nearly being commensurate with an Earth day suggests forming a collaboration of observers well-separated in longitude.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/20	14 41.6	-16 02	0.23	1.18	18.3	35.7	136	151	+0.35	+39
03/22	14 46.7	-18 15	0.20	1.15	18.0	36.5	136	129	+0.54	+37
03/24	14 53.4	-21 12	0.18	1.13	17.6	37.8	136	106	+0.73	+33
03/26	15 02.8	-25 14	0.15	1.11	17.2	40.2	134	83	+0.90	+29
03/28	15 17.3	-31 00	0.12	1.08	16.9	44.2	131	60	+0.99	+22
03/30	15 42.9	-39 37	0.10	1.06	16.5	51.5	124	42	-0.98	+12
04/01	16 39.4	-52 14	0.08	1.03	16.4	64.3	112	36	-0.85	-4
04/03	19 17.2	-64 35	0.07	1.00	16.7	84.6	92	43	-0.66	-27

References

Abe, M.; Kawakami, K.; Hasegawa, S.; Kuroda, D.; Yoshikawa, M.; Kasuga, T.; Kitazato, K.; Sarugaku, Y.; Kinoshita, D.; Miyasaka, S.; Urakawa, S.; Okumura, S.; Takagi, Y.; Takato, N.; Fujiyoshi, T.; Terada, H.; Wada, T.; Ita, Y.; Vilas, F.; Weissman, R.P. (2008). "Ground-based Observational Campaign for Asteroid 162173 1999 JU3." *Lunar & Planetary Sci. XXXIX*. No. 1391, p. 1594.

Behrend, R. (2005). Observatoire de Geneve web site. http://obswww.unige.ch/~behrend/page_cou.html

Binzel, R.P.; DeMeo, F.E.; Turtelboom, E.V.; Bus, S.J.; Tokunaga, A.; Burbine, T.H.; Lantz, C.; Polishook, D.; Carry, B.; Morbidelli, A.; Birlan, M.; Vernazza, P.; Burt, B.J.; Moskovitz, N.; Slivan, S.M.; Thomas, C.A.; Rivkin, A.S.; Hicks, M.D.; Dunn, T.; Reddy, V.; Sanchez, J.A.; Granvik, M.; Kohout, T. (2019). "Compositional distributions and evolutionary processes for the near-Earth object population: Results from the MIT-Hawaii Near-Earth Object Spectroscopic Survey (MITHNEOS)." *Icarus* **324**, 41-76.

Dose, E. (2021). "A New Photometric Workflow and Lightcurves of Fifteen Asteroids." *Minor Planet Bull.* **47**, 324-330.

Harris, A.W.; Young, J.W.; Contreiras, L.; Dockweiler, T.; Belkora, L.; Salo, H.; Harris, W.D.; Bowell, E.; Poutanen, M.; Binzel, R.P.; Tholen, D.J.; Wang, S. (1989). "Phase relations of high albedo asteroids: The unusual opposition brightening of 44 Nysa and 64 Angelina." *Icarus* **81**, 365-374.

Mainzer, A.K.; Bauer, J.M.; Cutri, R.M.; Grav, T.; Kramer, E.A.; Masiero, J.R.; Nugent, C.R.; Sonnett, S.M.; Stevenson, R.A.; Wright, E.L. (2016). "NEOWISE Diameters and Albedos V1.0." NASA Planetary Data System.

Masiero, J.R.; Redwing, E.; Mainzer, A.K.; Bauer, J.M.; Cutri, R.M.; Grav, T.; Kramer, E.; Nugent, C.R.; Sonnett, S.; Wright, E.L. (2018). "Small and Nearby NEOs Observed by NEOWISE During the First Three Years of Survey: Physical Properties." *Astron. J.* **156**, A60.

Mottola, S.; De Angelis, G.; Di Martino, M.; Erikson, A.; Hahn, G.; Neukum, G. (1995). "The near-earth objects follow-up program: First results." *Icarus* **117**, 62-70.

Muñonen, K.; Belskaya, I.N.; Cellino, A.; Delbò, M.; Levasseur-Regourd, A.-C.; Penttilä, A.; Tedesco, E.F. (2010). "A three-parameter magnitude phase function for asteroids." *Icarus* **209**, 542-555.

Müller, T.G.; Ďurech, J.; Hasegawa, S.; Abe, M.; Kawakami, K.; Kasuga, T.; Kinoshita, D.; Kuroda, D.; Urakawa, S.; Okumura, S.; Sarugaku, Y.; Miyasaka, S.; Takagi, Y.; Weissman, P.R.; Choi, Y.-J.; Larson, S.; Yanagisawa, K.; Nagayama, S. (2011). "Thermo-physical properties of 162173 (1999 JU3), a potential flyby and rendezvous target for interplanetary missions." *Astron. Astrophys.* **525**, A145.

Oey, J. (2014). "Lightcurve Analysis of Asteroids from Blue Mountains Observatory in 2013." *Minor Planet Bull.* **41**, 276-281.

Pilcher, F. (2020). "Lightcurves and Rotation Periods of 83 Beatrix, 86 Semele, 118 Peitho, 153 Hilda, 527 Euryanthe, and 549 Jessonda." *Minor Planet Bull.* **47**, 192-195.

Pravec, P.; Hergenrother, C.; Whiteley, R.; Sarounova, L.; Kusnirak, P.; Wolf, M. (2000). "Fast Rotating Asteroids 1999 TY2, 1999 SF10, and 1998 WB2." *Icarus* **147**, 477-486.

Pravec, P.; Harris, A.W.; Scheirich, P.; Kušnirák, P.; Šarounová, L.; Hergenrother, C.W.; Mottola, S.; Hicks, M.D.; Masi, G.; Krugly, Yu.N.; Shevchenko, V.G.; Nolan, M.C.; Howell, E.S.; Kaasalainen, M.; Galád, A.; Brown, P.; Degraff, D.R.; Lambert, J.V.; Cooney, W.R.; Foglia, S. (2005). "Tumbling asteroids." *Icarus* **173**, 108-131.