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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2023 OCTOBER-DECEMBER

Brian D. Warner
Center for Solar System Studies (CS3)
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinPlanObs.org

Alan W. Harris
Center for Solar System Studies (CS3)
La Cañada, CA 91011-3364 USA

Josef Ďurech
Astronomical Institute
Charles University
18000 Prague, CZECH REPUBLIC
durech@sirrah.troja.mff.cuni.cz

Lance A.M. Benner
Jet Propulsion Laboratory
Pasadena, CA 91109-8099 USA
lance.benner@jpl.nasa.gov

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. The "Radar-Optical Opportunities" section includes a list of potential radar targets as well as some that might be in critical need of astrometric data.

We present several lists of asteroids that are prime targets for photometry and/or astrometry during the period 2023 October through December. The "Radar-Optical Opportunities" section provides an expanded list of potential NEA targets, many of which are planned or good candidates for radar observations.

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., 2009) documentation for an explanation of the U code:

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

The ephemeris generator on the MinorPlanet.info web site allows creating 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.

https://www.minorplanet.info/php/callopplcdbquery.php

We refer you to past articles, e.g., Warner et al. (2021a; 2021b) 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

The database contains more than 10.4 million observations for 24,202 objects (as of 2023 April 6), making it one of the more useful sources for raw data of *dense* time-series asteroid photometry.

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 or have only a lower limit on the period, should be given higher priority over those rated U = 2 or 2+. 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.

All objects are reaching one of their five brightest apparitions from 1995-2050. Bold text indicates a near-Earth asteroid (NEA).

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
1033	Simona	10 01.7	14.6	+3	10.07	0.04	1+
34155	2000 QJ22	10 02.2	15.4	-12	3.008	0.10	2+
9333	Hiraimasa	10 03.3	15.5	-10	6.911	0.37	2+
2165	Young	10 04.3	14.7	+4	6.389		2
7355	Bottke	10 06.1	15.1	-6	2.636	0.21	2
1112	Polonia	10 08.1	13.8	+18	18.71	0.12-0.26	2
5417	Solovaya	10 08.6	15.4	+8	3.833	0.09	2+
35360	1997 TY11	10 08.8	15.5	+1	2.896	0.11	2
2437	Amnestia	10 13.9	14.4	+10	85	0.45-0.51	2
1332	Marconia	10 18.9	14.0	+10	19.16	0.30-0.4	2
12332	1992 UJ6	10 22.8	15.5	+10	43	0.62	2
9262	Bordovitsyna	10 23.7	15.3	+24	9	0.08	2
26853	1992 UQ2	10 28.9	14.9	+4	8.27	0.14	2+
14835	Holdridge	10 29.4	14.5	+30	>10	0.08	2-
3242	Bakhchisaraj	10 30.1	15.4	+5	15	0.07	2-
2889	Brno	11 02.2	15.2	+15	9.51	0.42-0.80	2+
3576	Galina	11 02.3	15.3	+21	3.342	0.04-0.15	2
14031	Rozyo	11 02.4	15.3	-4	S 2.901		2
3819	Robinson	11 03.3	14.9	+13	3.7	0.10-0.32	2+
8142	Zolotov	11 04.7	15.4	+15	4.323		2-
2203	van Rhijn	11 06.8	14.8	+16	30.55	0.38	2
3415	Danby	11 07.1	15.1	+17	5.675	0.09-0.35	2+
363505	2003 UC20#	11 07.5	14.3	-66	29.6	0.88	2+
1429	Pemba	11 10.1	13.8	+17	>20	0.3	1
3589	Loyola	11 13.1	15.3	+10	4.166		2
2716	Tuulikki	11 13.4	15.5	+16	50.18	0.05-0.12	2
3148	Grechko	11 15.1	15.4	+19	5.983	0.34-0.35	2
6086	Vrchlicky	11 17.1	15.0	+16	2.768	0.05	2
7201	Kuritariku	11 17.3	15.5	+21	S 48.849		2
2959	Scholl	11 17.6	15.2	+12	4.359	0.14	2+
27136	1998 XJ16	11 18.7	15.3	+6	26	0.10	2-
82256	2001 KM8	11 19.8	15.4	+13	3.036	0.34	2
4264	Karljosephine	11 19.9	14.9	+14	30.96	0.09-0.45	2
3442	Yashin	11 21.8	15.5	+7	8.552	0.50	2
4458	Oizumi	11 28.8	15.5	+17	S11.406		2
2269	Efremiana	11 30.8	15.0	+22	6.458	0.09	2
8021	Walter	12 07.2	15.4	+5	4.84	0.07	2
3629	Lebedinskij	12 08.9	15.3	+19	9.342	0.33	2+
10936	1998 FN11	12 10.9	14.8	+8	25.7	0.28-0.40	2
19370	Yukyung	12 18.7	15.0	+22	15.185	0.14-0.15	2
5765	Izett	12 22.2	14.8	+34	8.955	0.29	2+
1504	Lappeenranta	12 22.8	13.8	+22	15.19	0.09-0.29	2+
2140	Kemerovo	12 27.1	15.3	+23	9.2	0.18-0.19	2

Low Phase Angle Opportunities

The Low Phase Angle list includes asteroids that reach very low phase angles ($\alpha < 1°$). 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.

https://www.minorplanet.info/php/callopplcdbquery.php

The best chance of success comes with covering at least half a cycle a night, meaning periods generally < 16 h, when working objects with low amplitude. 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. Refer to Harris et al. (1989) for the details of the analysis procedure.

As an aside, it is arguably better for physical interpretation (e.g., *G* value versus albedo) to use the maximum light rather than mean level to find the phase slope parameter (*G*), which better models the behavior of a spherical object of the same albedo, but it can produce significantly different values for both *H* and *G* versus using average light, which is the method used for values listed by the Minor Planet Center. Using and reporting the results of both methods can provide additional insights into the physical properties of an asteroid.

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, and hopefully not until a discontinuity flaw in the G_{12} function has been fixed. 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° 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° intervals should be sufficient. Coverage beyond 50° or so is not generally helpful since the H-G system is best defined with data from 0-30°.

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 Gaia2/3. Catalogs such as CMC-15, APASS, or the MPOSC from *MPO Canopus* have too high systematic errors.

Also important is that 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.* If necessary, the magnitudes for a 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.

The asteroid magnitudes are brighter than in others lists because higher precision is required and the asteroid may be a full magnitude or fainter when it reaches phase angles out to 20-30°. Even so, starting now, the list will include objects that reach $V \leq 15.0$ at opposition. The list of objects using the previous limit of $V \leq 14.0$ was becoming very short.

Num	Name	Date	α	V	Dec	Period	Amp	U
492	Gismonda	10 01.8	0.63	13.3	+2	6.488	0.10 0.14	3
29	Amphitrite	10 02.2	0.90	8.8	+5	5.392	0.04 0.15	3
428	Monachia	10 04.1	0.86	13.4	+3	3.634	0.16 0.37	3
204	Kallisto	10 17.9	0.12	12.7	+9	19.489	0.09 0.26	3
1332	Marconia	10 18.9	0.29	14.0	+10	19.16	0.30 0.4	2
717	Wisibada	10 20.1	0.83	13.6	+12			
1204	Renzia	10 21.0	0.74	13.1	+12	7.885	0.42 0.49	3
122	Gerda	10 23.7	0.38	12.2	+10	10.685	0.10 0.26	3
1675	Simonida	10 24.9	0.13	13.7	+12	5.289	0.16 0.65	3
184	Dejopeja	10 28.6	0.43	13.1	+14	6.44	0.22 0.3	3
509	Iolanda	10 29.9	0.27	12.1	+14	12.306	0.20 0.45	3
127	Johanna	10 30.7	0.46	12.1	+15	12.799	0.18 0.21	3
343	Ostara	10 30.7	0.23	12.9	+13	109.87	0.52	3-
641	Agnes	11 03.9	0.12	13.9	+15	178.0	0.55	3
299	Thora	11 06.1	0.39	13.9	+17	272.9	0.37 0.50	3-
743	Eugenisis	11 06.9	0.27	13.6	+17	10.23	0.10-0.20	3
1429	Pemba	11 10.3	0.19	13.9	+17	>20.	0.3	1
90	Antiope	11 15.8	0.30	12.7	+18	16.509	0.05-0.88	3

Num	Name	Date	α	V	Dec	Period	Amp	U
363	Padua	11 21.6	0.39	12.4	+19	8.401	0.08-0.3	3
425	Cornelia	11 21.8	0.12	13.8	+20	17.505	0.19-0.21	3
24	Themis	11 23.1	0.15	11.4	+21	8.374	0.09-0.14	3
503	Evelyn	11 24.5	0.47	12.1	+19	38.871	0.30-0.5	3
1133	Lugduna	11 24.5	0.41	13.6	+21	5.477	0.33-0.49	3
300	Geraldina	11 29.2	0.17	14.0	+22	6.842	0.04-0.32	3
95	Arethusa	11 30.4	0.65	11.4	+20	8.705	0.24-0.35	3
149	Medusa	12 14.8	0.84	12.5	+21	26.023	0.47-0.56	3
488	Kreusa	12 18.7	0.34	11.8	+24	32.645	0.08-0.20	3
1504	Lappeenranta	12 22.7	0.75	13.9	+22	15.190	0.09-0.29	2+
1176	Lucidor	12 27.0	0.21	14.0	+23	4.079	0.05-0.06	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 ≥ 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.

With the wide use of sparse data from the surveys for modeling that produces hundreds of statistically valid poles and shapes, the need for data for main-belt objects is not what it used to be. The best use of observing time might be to concentrate on near-Earth asteroids, or on asteroids where the only period was derived from sparse data, which can help eliminate alias periods.

The latter targets are usually flagged with an 'S' on the LCDB summary line. Regardless, it's a good idea to visit the DAMIT site and see what it has, if anything, on the target(s) you've picked for observations.

All objects are at a favorable apparition. Those in italic text are near-Earth objects.

		Brightest			LCDB Data		
Num	Name	Date	Mag	Dec	Period	Amp	U
4254	Kamel	10 09.0	14.8	+8	2.739	0.17-0.19	3
7778	Markrobinson	10 15.9	14.9	+24	7.23	0.64-0.84	3
24643	MacCready	10 21.8	15.4	+21	2.829	0.11-0.20	3
7350	1993 VA#	10 23.9	15.4	-47	3.583	0.15-0.38	3
164121	2003 YT1#	11 02.6	12.2	-20	2.343	0.16-0.27	3
1362	Griqua	11 03.3	14.2	-25	6.907	0.23-0.25	3
3567	Alvema	11 04.8	14.9	+25	8.17	0.17-0.45	3-
3838	Epona#	11 18.1	15.4	+17	2.381	0.05-0.38	3
363	Padua	11 21.6	12.4	+19	8.401	0.08-0.3	3
481	Emita	11 21.6	11.4	+17	14.412	0.13-0.30	3
895	Helio	11 24.5	12.4	+37	9.347	0.09-0.23	3
346	Hermentaria	11 27.0	10.7	+14	28.523	0.07-0.20	3
4700	Carusi	11 30.3	14.8	+20	11.671	0.11-0.53	3-
1316	Kasan	12 01.7	14.6	+9	5.843	0.19-0.26	3
5536	Honeycutt	12 02.9	14.9	+22	3.583	0.08-0.09	3
815	Coppelia	12 09.0	14.1	+31	4.421	0.13-0.24	3
6170	Levasseur	12 13.6	15.4	+69	2.653	0.09-0.14	3
1011	Laodamia	12 16.1	13.6	+13	5.172	0.41-0.45	3

Radar-Optical Opportunities

Table I below gives a list of near-Earth asteroids reaching maximum brightness for the current quarter-year based on calculations by Warner. We switched to this presentation in lieu of ephemerides for reasons outlined in the 2021 October-December opportunities paper (Warner et al., 2021b), which centered on the potential problems with ephemerides generated several months before publication.

The initial list of targets started using the planning tool at

https://www.minorplanet.info/php/callopplcdbquery.php

where the search was limited to near-Earth asteroids only that were V ≤ 18 for at least part of the quarter.

The list was then filtered to include objects that might be targets for the Goldstone radar facility or, if it were still operational, the Arecibo radar. This was based on the calculated radar SNR using

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

and assuming a rotation period of 4 hours (2 hours if $D \leq 200$ m) if a period was not given in the asteroid lightcurve database (LCDB; Warner et al., 2009). The SNR values are estimates only and assume that the radar is fully functional.

If an asteroid was on the list but failed the SNR test, we checked if it might be a suitable target for radar and/or photometry sometime through 2050. If so, it was kept on the list to encourage physical and astrometric observations during the current apparition. In most of those cases, the SNR values in the "A" and "G" columns are not for the current quarter but the year given in the Notes column. If a better apparition is forthcoming through 2050, the Notes column in Table I contains SNR values for that time.

The final step was to cross-reference our list with that found on the Goldstone planned targets schedule at

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

In Table I, objects in bold text are on the Goldstone proposed observing list as of 2023 July.

It's important to note that the final list in Table I is based on *known* targets and orbital elements when it was prepared. It is common for newly discovered objects to move in or out of the list. We recommend that you keep up with the latest discoveries by using 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.

For observation planning, use these two sites

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

Cross-check the ephemerides from the two sites just in case there is discrepancy that might have you imaging an empty sky.

About YORP Acceleration

Near-Earth asteroids are particularly sensitive to YORP acceleration. YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack; Rubincam, 2000) 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.

The Quarterly Target List Table

The Table I columns are

Num	Asteroid number, if any.
Name	Name assigned by the MPC.
H	Absolute magnitude from MPCOrb.
Dkm	Diameter (km) assuming $p_V = 0.2$.
Date	Date (mm dd.d) of brightest magnitude.
V	Approximate V magnitude at brightest.
Dec	Approximate declination at brightest.
Period	Synodic rotation period from summary line in the LCDB summary table.
Amp	Amplitude range (or single value) of reported lightcurves.
U	LCDB U (solution quality) from 1 (probably wrong) to 3 (secure).
A	Approximate SNR for Arecibo (if operational and at full power).
G	Approximate SNR for Goldstone radar at full power.
Notes	Comments about the object.

"PHA" is a potentially hazardous asteroid. NHATS is for "Near-Earth Object Human Space Flight Accessible Targets Study." Presume that that astrometry and photometry have been requested to support Goldstone observations. The sources for the rotation period are given in the Notes column. If none are qualified with a specific period, then the periods from multiple sources were in general agreement. Higher priority should be given to those where the current apparition is the last one V ≤ 18 through 2050 or several years to come.

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Num	Name	H	Diam	BDate	BMag	BDec	Period	AMn	AMx	U	A	G	Notes
349507	**2008 QY**	**18.54**	**0.582**	**10 06.7**	**14.8**	**23**					**910**	**260**	
518635	2008 HO3	18.2	0.681	10 11.5	15.5	17	13.413		0.88		25		Warner/Stephens (2019)
	2011 GA	**20.8**	**0.193**	**10 16.9**	**15.0**	**-5**							**PHA.**
	1998 HH49	**21.3**	**0.161**	**10 17.9**	**13.1**	**-2**							**PHA.**
7350	1993 VA	17.28	1.04	10 23.9	15.4	-47	3.58264	0.15	0.38	3	25	-	
	2019 HH4	**19.9**	**0.307**	**10 27.2**	**17.0**	**-35**							**PHA.**
302169	**2001 TD45**	**19.89**	**0.313**	**10 28.3**	**15.1**	**79**					**750**	**215**	**PHA.**
525229	**2004 UU1**	**21.25**	**0.167**	**10 31.5**	**14.2**	**10**					**625**	**180**	**PHA.**
31669	1999 JT6	16.15	1.75	11 01.9	17.0	12	5.807	0.07	0.27	3	-	-	Galad et al. (2005)
164121	**2003 YT1**	**16.33**	**1.61**	**11 02.6**	**12.2**	**-20**	**2.343**	**0.16**	**0.27**	**3**	**970**	**280**	**PHA. Binary. Nolan et al. (2004); Pravec et al. (2006)**
363505	**2003 UC20**	**18.5**	**0.593**	**11 07.5**	**14.3**	**-66**	**29.6**		**0.88**	**2+**	**6010**	**1725**	**PHA. NHATS. Pravec et al. (2019web)**
25330	1999 KV4	16.79	1.3	11 14.2	14.8	19	4.919	0.14	0.15	3	-	-	Pravec et al. (2002web)
3838	Epona	15.71	2.14	11 18.1	15.4	17	2.3812	0.05	0.38	3	-	-	Pravec et al. (1999web)
1943	Anteros	15.89	1.97	11 19.2	16.7	23	2.86923	0.07	0.14	3	-	-	Binary. Warner et al. (2017)
219071	1997 US9	17.18	1.09	11 24.4	16.8	-20	3.319	0.14	0.20	3-	-	-	Skiff et al. (2019)
	1998 WB2	**21.8**	**0.113**	**12 01.3**	**16.2**	**43**	**0.313**		**0.6**	**3**	**115**	**35**	**PHA. Pravec et al. (2000)**
13962	**2001 QQ142**	**18.5**	**0.593**	**12 10.4**	**14.2**	**-6**					**4850**	**1390**	**NHATS.**
326683	2002 WP	18.54	0.582	12 11.0	16.2	36	6.262	1.13	1.65	3	-	-	Behrend (2016web)
137671	1999 XP35	18.7	0.541	12 12.8	17.0	34					-	-	
341843	**2008 EV5**	**20.07**	**0.288**	**12 24.9**	**15.9**	**-2**	**3.725**	**0.03**	**0.15**	**3**	**350**	**100**	**NHATS. Galad et al. (2009)**
	2018 YJ2	**21.8**	**0.129**	**12 26.2**	**18.1**	**78**					**-**	**-**	**PHA.**
168318	1989 DA	18.98	0.475	12 28.4	16.7	71	3.925		0.12	3	10	-	Wisniewski et al. (1997)

Table I. A list of near-Earth asteroids reaching brightest in 2023 January-March. PHA: potentially hazardous asteroid. NHATS: Near-Earth Object Human Space Flight Accessible Targets Study. Diameters are based on p_V = 0.20. The Date, V, and Dec columns are the mm/dd.d, approximate magnitude, and declination when at brightest. Amp is the single or range of amplitudes. The A and G columns are the approximate SNRs for an assumed full-power Arecibo (not operational) and Goldstone radars. The references in the Notes column are those for the adopted period.

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