ASTEROID LIGHTCURVE DATA BASE (LCDB)

Revised 2021 November 16

SPECIAL NOTICES

The README.txt file is no longer distributed. Only the bookmarked PDF version is included.

2021 November VERY IMPORTANT

Changes Regarding Phase Slope Parameter G, G1, and G2

At the suggestion of several data providers, the LCDB has split the H-G(1,2), i.e., there are fields for G, G1, and G2. The G field is no longer used for G1 under the HG12 system.

The LCDB does *not* distinguish between the HG1,G2 and HG12 systems. If both sets are provided, the HG12 values are used. If only HG1,G2 values are provided, they are entered as if HG12 values. It is worth noting that the HG12 system is often used when the range of phase angle observations was too limited to find a valid value for G2 and so only a G1 value could be found. See section *3.1.1 THE H-G, H-G12, and H-G1,G2 SYSTEMS.*

2021 April VERY IMPORTANT

Changes Regarding Phase Slope Parameter G(1), G2

To accommodate the currently adopted absolute magnitude/phase slope parameter H-G12 (H-G1,2) systems that replaced the traditional H-G system, new fields have been added to the Summary and Details tables and reports. See section *3.1.1 THE H-G, H-G12, and H-G1,G2 SYSTEMS.*

Changes Regarding Groups/Families

The LCDB has been revised to use a hybrid of the Nesvorny (2015) and Nesvorny et al. (2015) families and those defined on the AstDys (2021) web site. As such, all entries in the “Family” column in those reports that include it, now have a text value that represents a number from either the Nesvorny or AstDys site family definitions. See section *3.1.2 FAMILY/GROUP MEMBERSHIP, DEFAULT ALBEDOS, AND TAXONOIMC* CLASS.

File Name Changes

The file names in the distribution have been changed to match those in the set submitted to the NASA Planetary Data System Small Bodies Node. See section *2.1.0 DISTRIBUTION FILES* for the revised file list.

As a result of the changes above, column mappings for the lc_summary, lc_details, and lc_diameters reports have changed and there is a new lc_familylookup table. The new listings are given the appropriate subsections of Section 4.

2020 December
The CLASS column in the Summary and Details table was expanded to 10 characters. This changed the column mapping for this and all subsequent columns.

2020 March
The structure of the lc_colorindex table was changed to include the R-I (Cousins) color index after the V-I color index and the ATLAS c-o color index as the last column. The column mapping has been updated.

2020 February
The structure of the Summary and Details table was changed. The "sparse" and "wide" fields were replaced by a single "survey" field. The net effect to the column mapping is only that the survey field starts in the same location as the Sparse field and has the same width.

See Section 5 "HANDLING SURVEY DATA" (updated 2020 February 10)

See Section 6, “NUMBERS OF INTEREST”

New: Section 7, “REFERENCES”. This list the citations for the references mentioned in this file.

The Min/Max Amplitude values in the Summary table are based only on detail lines that have U ≥ 2- ratings. If the U code is empty or U ≤ 1+, the detail line min/max amplitudes are not considered.

Floating point numbers are stored as strings in the LCDB. This preserves the original precision of the data. It is up to the end user to maintain the original precision if/when converting string representations to real values.

N.B. All lightcurve amplitudes are peak-to-peak, not average-to-peak.

ASTEROID NAMES

In recent times, asteroid names have included characters that are not easily represented under extended ASCII encoding. For this reason, the ASCII names are used in the LCDB, i.e., no diacritical marks are included. For a more accurate listing, the user is referred to the MPC site

https://www.minorplanetcenter.net/iau/lists/MPNames.html

which gives the current list of numbered/named asteroids. Even this list, however, does not completely cover all cases. For example,

(229762) G!kún‖'hòmdímà

appears as

G!kun||'homdima

in the MPC listing.

PHOTOMETRIC BAND NAMES

To avoid issues with upper/lower case photometric bands, e.g., r vs. R for Sloan r´ vs. Cousins R, the Sloan band names have be prepended with ‘S’ and made upper case, e.g., r´ => SR. For ATLAS o and c bands, AO and AC are used. For Gaia G, GG is used to distinguish it from Sloan g´.

1.0.0 INTRODUCTION

The Asteroid Lightcurve Data Base (LCDB) is a set of tables generated from a MySQL database that includes information directly and indirectly obtained from observations made to determine the period and/or amplitude of asteroid lightcurves. The information is taken from numerous journals and other sources.

Its main purpose is to provide a central location for basic information about asteroid rotation rates and related information that can be used in statistical studies involving a few or many parameters. Some of the data are obtained directly from the observations while other data are inferred or calculated based on orbital characteristics, assumed class, etc.

Sections below explain in detail which data are direct and indirectly obtained and, for the latter, their derivation.

N.B. Even direct data should be confirmed by reference to the original works whenever possible. Indirect data are provided for information purposes only. They should not be used in critical studies.

1.1.0 AUTHOR INFORMATION

These data tables are maintained by Brian D. Warner (Center for Solar System Studies/MoreData!, Alan Harris (MoreData!), and Petr Pravec (Astronomical Institute, Prague, Czech Republic).

For basic information on the database or updated versions of the tables, contact:

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1.2.0 DISCLAIMER

We have made every attempt to keep the data up to date and correct. However, we know that there is the possibility for omissions or errors. Please let us know of any corrections or additions by sending email to one of the below.

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Alan Harris harrisaw@att.net

2.0.0 DATA FILES

The LCDB release consists of 10 primary files (tables). Also included is the pds_readme.pdf (this file), which provides detailed information about the LCDB and the 10 tables.

2.0.1 AVAILABILITY OF RAW DATA FILES

The raw databases files are MySQL tables. These are used on the alcdef.org and minorplanet.info web sites for user-defined searches. Starting sometime in 2020, the alcdef.org site will be part of the Small Bodies Node hosted by the University of Maryland.

The MySQL tables are not generally available. However, we can - on a limited basis - provide CSV (actually, semi-colon) files generated from the database files that can used with the SQL CLOAD command to populate local MySQL files.

2.1.0 DISTRIBUTION FILES

The file names were changed in 2021 March to match the base names used in the release to NASA's Planetary Data Systems Small Bodies Node. To avoid confusion with the PDS files, the names of the files for the general LCDB release will include a _pub suffix, e.g., lc_binary_pub.txt.

readme.pdf	This file of introductory information.
lc_ambiguous	Asteroids with ambiguous periods.
lc_binary	Suspected/confirmed binary/multiple asteroids
lc_colorindex	Color indexes of asteroids (B-V, V-R, V-I, g-r, r-i, B-R).
lc_details	Basic summary Table 1nformation and the detailed information from individual references. There are one or more lines per asteroid.
lc_diameters	Summary H, p_V, D values and the same values plus errors from detail records that reported a diameter.
lc_familylookup	Families and orbital groups used in the LCDB and default albedo, G, and taxonomic class for each one.

lc_exnotes	Extended notes associated with summary and/or details records.
lc_npa	Suspected/confirmed asteroids in non-principal axis rotation (NPAR, or "tumbling").
lc_references	Publications referenced in the LCDB.
lc_spinaxis	Asteroids with reported spin axis (poles) and/or shape models.
lc_summary	Summary data, one line per asteroid, no references.

2.1.1 SPIN AXIS CATALOGS

As noted above, the lc_spinaxis table stores information about the spin axis properties (ecliptic coordinates and sidereal periods). A more thorough and complete catalog is maintained by Kryszczynska et al. at the Poznan Observatory in Poland.

That catalog can be accessed via

http://vesta.astro.amu.edu.pl/Science/Asteroids/

Josef Durech (Durech et al., 2010) also maintains a list of spin axis solutions, with shape models and data files. His site is at

http://astro.troja.mff.cuni.cz/projects/asteroids3D/

It should be noted that the favored DAMIT pole may differ from the one in the original reference. This is usually because Durech and associates did a new analysis with the original, updated, and/or new data. Their revised result replaced the original instead of indicating a new result under a different reference.

Because of the complexities of cross-checking the LCDB vs. DAMIT vs. original result, the LCDB does not directly include any DAMIT results, i.e., there are no entries with DAMIT being the author reference. When and if revised results are published in one of the journals, those results will be included in the LCDB.

2.2.0 BINARY ASTEROID FILES

In addition to the lc_binary table, Petr Pravec (Astronomical Institute, Prague, Czech Republic) maintains a considerably more detailed set of files:

BINARY_README.TXT	Separate README pertaining the binary asteroid
BINASTD_PUB.TXT	The best estimates of compiled parameters
BINASTE_PUB.TXT	Uncertainties of the estimates in BINASTD_PUB.TXT
BINASTM_PUB.TXT	References and notes for the compiled estimates

BINASTR_PUB.TXT   Information on each of the estimates, e.g., their derivation

These files are not included in the PDS release but are available at

http://www.asu.cas.cz/~asteroid/binastdata.htm

2.2.1 ABOUT BINARY DATA

The data in the lc_binary table are by no means exhaustive. They are meant to provide a quick overview of the primary period and amplitude as well as a secondary period and/or orbital period and, if available, amplitude. Also included, if available, are the depth (magnitude drop) of mutual events, the Ds/Dp (effective diameter) ratio of satellite to primary, and ADp (semi-major axis to primary diameter ratio).

The reader is urged to consult the original journal articles for more complete details.

See the web site run by Wm. Robert Johnston

http://www.johnstonsarchive.net/astro/asteroidmoons.html

3.0.0 LCDB DATA

The original lightcurve database was a simple text file with a structure that tried to minimize disk space requirements. That served well for many years. However, the rapidly growing number of lightcurves being reported as well as the file's format not being able to accommodate some data prompted a change starting in mid-2006.

The foremost change was converting to a relational database that included numerous tables and had SQL search capabilities. This allowed for not only easier maintenance of the database but for generating reports in a way that are more informative, complete, and consistent in formatting.

The sections below provide the formatting for each field in each table. Of particular importance is to note the -maximum- precision of floating point numbers is not always the actual precision of the reported value. In critical studies, it is important for end-users to keep the original precision of the values.

3.1.0 DIRECT DATA

Data that are obtained directly from photometric observations includes

1. Rotation period (usually synodic).
2. Amplitude.
3. Absolute magnitude, H, and phase slope parameter, G or G12, when determined by using reduced magnitude versus phase angle data.
4. Binarity due to mutual events, i.e., occultations and eclipses. In such cases, the rotation period of the primary and orbital period of the satellite and the amplitude of the primary lightcurve are the usual direct results. The size ratio can be computed from the depth of the events. For more details on binary lightcurve analysis, see Pravec et al. (2006).
5. Color indices.
6. Diameter if based on stellar occultation or adaptive optics/radar. Radar diameters can also be considered indirect depending on how the diameter was determined.
7. Taxonomic class.

3.1.1 THE H-G, H-G12, and H-G1,G2 SYSTEMS

To predict the magnitude of an asteroid and how it changes with phase angle versus a linear geometrical relationship, the H-G system (Bowell et al., 1989) was adopted by the IAU in 1985. A new system involving three parameters (Muinonen et al., 2010) was adopted by the IAU, although the H-G system still remains in wide use. Even so, the use of H-G12 system is becoming more common and so the LCDB tables have been altered to account for the new data format.

The H-G12 system uses only the first term of the two under the H- G1,G2 system and is most often used when there are limited data for finding a phase curve. The H-G1,G2 system uses two parameters that more effectively describe the asteroid's brightness at large and small phase angles. It has also been shown to be an effective tool for taxonomic classification (Shevchenko et al, 2016; Mahlke et al., 2021).

A strong discontinuity exists around G1 = 0.2 for the H-G12 and H-G1,G2 systems. See the Muinonen et al. (2010) paper for a discussion on this issue.

The large majority of G values given in the LCDB are under the H-G system. However, some surveys that produced large number of rotation periods also found G1 under H-G12 as part of their data reduction. To accommodate both systems, the Summary and Details tables include a "G1" and "G2" field.

In both tables, if the "GSource" field has no or a value other than 'G', the "G" data field is on the H-G system. If the "GSource" field has 'G', then the value in the "G1" field is G1 on the H-G12 or H-G1,G2 system. If the "G2" field has a value, then the "G2" field is G2 on the H-G1,G2 system.

The Diameters report (see section *4.5.0 LC_DIAMETERS*) also accommodates the G, G1, and G2 fields.

3.1.2 FAMILY/GROUP MEMBERSHIP, DEFAULT ALBEDOS, AND TAXONOIMC CLASS

Other than just rotation rates, the most common use of the LCDB is to plot rotation rate versus diameter. The tabulation of absolute magnitude (H), phase slope parameter (G), and albedo (p_V or other band) are used to document how the value for diameter (D) was determined. These values are not intended to be fundamental or all that carefully edited (see below). For the LCDB purposes, an error of even 50% is insignificant in a plot spanning five orders of magnitude. See section 3.1.2.1 CAVE USOR – USER BEWARE below.

Until 2021 April, the LCDB defined 33 "families," which were actually groups based on orbital parameters using osculating elements rather than membership in a collisional family. These were replaced by adopting the dynamical families defined under Nesvorny (2015) and Nesvorny et al. (2015) – from here on, *Nesvorny* refers to both references – and AstDys (2021) web site (see the numerous references available there). The most important element of the revision is that family membership is based on proper elements.

More so, *Nesvorny* used SDSS colors and WISE (Mainzer et al., 2019) albedos along with a parameter C_j to isolate objects that were more likely than not true family members (from the same parent) and not just occupying the orbital space of a family, what they called *dynamic interlopers*. For example, their list for the Hungaria family includes 2965 objects but 60 of those were flagged by the C_j parameter to by *dynamic interlopers*.

In the LCDB, any object not within one of the defined families is given an LCDB-defined family identification number (FIN; see *Nesvorny* for a discussion about the need and use of FINs) in the range 9000-9999.

Whether a true family member or a group member, a default albedo, taxonomic class, and G (on the H-G system) are assigned to an object when added to the LCDB, except in those cases when one or more of the actual values are known. These three values can have a complex relationship when the class and albedo are not directly obtained.

Nesvorny assigned default albedos and taxonomic class for most of the families in their list. As previously mentioned, the albedos are based on WISE observations, i.e., their *H* and the measured diameter were used to derive the albedo, while the taxonomic class was taken from the literature. When no actual values are available, the defaults are used. However, *Nesvorny* did not provide a default value for *G*. This value is assigned based on the adopted albedo as given in Table 1.

N.B. Whenever possible, the LCDB does not use the MPC default of $G = 0.15 \pm 0.20$. *However, keep in mind that the MPC H value is almost always based on that default.*

Beyond this, Table 1 (originally in Warner et al., 2009) is used to assign default values when at least one of the three parameters is known. These defaults were based on objects with known values for all three parameters at the time.

Taxonomic Classes	Albedo	G
C, G, B, F, P, T, D	0.057 ± 0.02	0.12 ± 0.08
M	0.16 ± 0.04	0.20 ± 0.07
S, Q	0.20 ± 0.07	0.24 ± 0.11
E, V, R	0.46 ± 0.06	0.43 ± 0.08

Table 3.1.2.1. Inter-relation of default taxonomic class, albedo, and G (H-G) from Warner et al. (2009)

When all else failed, the three parameters from Table 1 were assigned based on membership in one of several broad orbital groups previously defined in Warner et al. (2009).

The *Nesvorny* family numbers were used for the initial assignments, including for those in AstDys families common to *Nesvorny*. However, there were 60 families in the AstDys list that were not in *Nesvorny*. These were assigned custom family numbers in the range 2000-2999.

Table 3.1.2.2 gives a full listing of the 202 family or orbital group assignments and default values used in the LCDB as of 2021 March.

The Number column is the family number that appears in the LCDB text reports. Nesvorny numbers range from 001-999. Family numbers 2001-2060 are dynamical families that appear only in the list on the AstDys (2021) web site. Numbers > 9100 are "catch all" orbital groups for those objects that could not be tied to a dynamic family. The family name is appended with an asterisk.

The *Parent* is the MPC-assigned number of the parent (largest) body of a family. The Name column is the name of the parent body. The albedo is usually that of the parent body as measure by WISE (Mainzer et al., 2019) or, for a small number, the average of several albedos of family members, again using WISE data.

If there is an asterisk after a class, it is assumed based on orbital location. Otherwise, it is the measured taxonomic class of the parent body. Count is the number of dynamic family members taken from the Nesvorny or AstDys lists.

Number	Parent	Name	Count	Albedo	Err	G	Err	Class
001	153	Hilda	409	0.038	0.007	0.12	0.08	P
002	1911	Schubart	352	0.039	0.013	0.12	0.08	P
003	434	Hungaria	2965	0.38	0.1	0.43	0.08	E
004	624	Hector	12	0.107	0.011	0.24	0.11	C
005	3548	Eurybates	218	0.052	0.007	0.12	0.08	C*
006	9799	1996 RJ	7	0.06	0.012	0.12	0.08	C*
008	20961	Arkesilaos	37	0.057	0.02	0.12	0.08	C*
009	4709	Ennomos	30	0.077	0.009	0.12	0.08	D

Number	Parent	Name	Count	Albedo	Err	G	Err	Class
010	247341	2001 UV209	13	0.088	0.023	0.12	0.08	C*
401	4	Vesta	15252	0.355	0.099	0.43	0.08	V
402	8	Flora	13786	0.24	0.01	0.24	0.11	S
403	298	Baptistina	2500	0.154	0.02	0.24	0.11	S*
404	20	Massalia	6424	0.249	0.07	0.24	0.11	S
405	44	Nysa-Polana	19073	0.48	0.02	0.43	0.08	E
406	163	Erigone	1776	0.055	0.013	0.12	0.08	C
407	302	Clarissa	179	0.054	0.02	0.12	0.08	F
408	752	Sulamitis	303	0.055	0.01	0.12	0.08	P
409	1892	Lucienne	142	0.25	0.03	0.24	0.11	S
410	27	Euterpe	474	0.22	0.01	0.24	0.11	S
411	1270	Datura	6	0.29	0.01	0.24	0.11	S
412	21509	Lucascavin	3	0.24	0.02	0.24	0.11	S*
413	84	Klio	330	0.053	0.002	0.12	0.08	C
414	623	Chimaera	108	0.035	0.004	0.12	0.08	Xc
415	313	Chaldaea	132	0.05	0.01	0.12	0.08	C
416	329	Svea	48	0.046	0.007	0.12	0.08	C
417	108138	2001 GB11	9	0.2	0.07	0.24	0.11	S*
501	3	Juno	1684	0.253	0.055	0.24	0.11	S
502	15	Eunomia	5670	0.26	0.083	0.24	0.11	S
504	128	Nemesis	1302	0.051	0.002	0.12	0.08	C
505	145	Adeona	2236	0.062	0.01	0.12	0.08	C
506	170	Maria	2940	0.261	0.084	0.24	0.11	S
507	363	Padua	1087	0.06	0.01	0.12	0.08	X
508	396	Aeolia	296	0.106	0.028	0.24	0.11	X
509	410	Chloris	424	0.05	0.01	0.12	0.08	C
510	569	Misa	702	0.058	0.016	0.12	0.08	C
511	606	Brangane	195	0.121	0.028	0.24	0.11	K
512	668	Dora	1259	0.058	0.014	0.12	0.08	C
513	808	Merxia	1215	0.248	0.055	0.24	0.11	S
514	847	Agnia	2125	0.242	0.056	0.24	0.11	S
515	1128	Astrid	489	0.052	0.014	0.12	0.08	C
516	1272	Gefion	2547	0.25	0.01	0.24	0.11	C*
517	3815	Konig	354	0.051	0.014	0.12	0.08	C*
518	1644	Rafita	1295	0.14	0.03	0.24	0.11	S
519	1726	Hoffmeister	1819	0.048	0.013	0.12	0.08	c*
520	4652	Iannini	150	0.26	0.05	0.24	0.11	S
521	7353	Kazuya	44	0.2	0.05	0.24	0.11	S*
522	173	Ino	463	0.07	0.02	0.12	0.08	X
523	14627	Emilkowalski	4	0.2	0.02	0.24	0.11	D
524	16598	Brugmansia	3	0.1	0.05	0.12	0.08	C*
525	2384	Schulhof	6	0.25	0.04	0.24	0.11	S*
526	53546	2000 BY6	58	0.057	0.02	0.12	0.08	C*
527	5438	5438 Lorre	2	0.05	0.02	0.12	0.08	C
528	2782	Leonidas	135	0.057	0.02	0.12	0.08	C*
529	144	Vibilia	180	0.05	0.01	0.12	0.08	C
530	322	Phaeo	146	0.08	0.02	0.12	0.08	C

Number	Parent	Name	Count	Albedo	Err	G	Err	Class
531	2262	Mitidika	653	0.21	0.04	0.24	0.11	S*
532	2085	Henan	1872	0.19	0.08	0.24	0.11	L
533	1668	Hanna	280	0.04	0.01	0.12	0.08	C*
534	3811	Karma	124	0.05	0.02	0.12	0.08	C*
535	2732	Witt	1816	0.3	0.03	0.24	0.11	S
536	2344	Xizang	275	0.09	0.01	0.12	0.08	C
537	729	Watsonia	99	0.13	0.02	0.24	0.11	L
538	3152	Jones	22	0.05	0.02	0.12	0.08	C
539	369	Aeria	272	0.16	0.02	0.24	0.11	M
540	89	Julia	33	0.18	0.02	0.24	0.11	K
541	1484	Postrema	108	0.038	0.014	0.12	0.08	C*
601	10	Hygiea	4854	0.073	0.022	0.12	0.08	C
602	24	Themis	4782	0.07	0.019	0.12	0.08	B
603	87	Sylvia	255	0.042	0.01	0.12	0.08	X
604	137	Meliboea	444	0.05	0.01	0.12	0.08	C
605	158	Koronis	5949	0.24	0.06	0.24	0.11	S
606	221	Eos	9789	0.157	0.05	0.24	0.11	C
607	283	Emma	76	0.049	0.013	0.12	0.08	P
608	293	Brasilia	579	0.174	0.042	0.24	0.11	X
609	490	Veritas	1294	0.06	0.01	0.12	0.08	C
610	832	Karin	541	0.22	0.04	0.24	0.11	S
611	845	Naema	301	0.065	0.014	0.12	0.08	C
612	1400	Tirela	1395	0.22	0.01	0.24	0.11	S*
613	3556	Lixiaohua	756	0.047	0.01	0.12	0.08	T
614	9506	Telramund	468	0.057	0.02	0.12	0.08	C*
615	18405	1993 FY12	104	0.184	0.042	0.24	0.11	S*
616	627	Charis	808	0.09	0.04	0.12	0.08	X
617	778	Theobalda	376	0.06	0.02	0.12	0.08	F
618	1189	Terentia	79	0.049	0.01	0.12	0.08	C
619	10811	Lau	56	0.26	0.02	0.24	0.11	S*
620	656	Beagle	148	0.08	0.02	0.12	0.08	C*
621	158	Koronis(2)	246	0.24	0.06	0.24	0.11	S
622	81	Terpsichore	138	0.05	0.01	0.12	0.08	C
623	709	Fringilla	134	0.04	0.01	0.12	0.08	P
624	5567	Durisen	27	0.058	0.015	0.12	0.08	C*
625	5614	Yakovlev	67	0.06	0.01	0.12	0.08	C*
626	7481	San Marcello	144	0.17	0.07	0.24	0.11	X
627	15454	1998 YB3	38	0.045	0.01	0.12	0.08	C*
628	15477	1999 CG1	248	0.057	0.02	0.12	0.08	C*
629	36256	1999 XT17	58	0.19	0.04	0.24	0.11	A
630	96	Aegle	99	0.051	0.01	0.12	0.08	T
631	375	Ursula	1466	0.062	0.015	0.12	0.08	X
632	618	Elfriede	63	0.057	0.02	0.12	0.08	C
633	918	Itha	54	0.19	0.02	0.24	0.11	C*
634	3438	Inarradas	38	0.06	0.02	0.12	0.08	C
635	7468	Anfimov	58	0.257	0.04	0.24	0.11	S*
636	1332	Marconia	34	0.051	0.01	0.12	0.08	L

Number	Parent	Name	Count	Albedo	Err	G	Err	Class
637	106302	2000 UJ87	64	0.044	0.01	0.12	0.08	C*
638	589	Croatia	93	0.049	0.01	0.12	0.08	C
639	926	Imhilde	43	0.055	0.01	0.12	0.08	C
641	816	Juliana	76	0.037	0.02	0.12	0.08	C*
701	25	Phocaea	1989	0.253	0.117	0.24	0.11	S
801	2	Pallas	128	0.14	0.02	0.24	0.11	B
802	148	Gallia	182	0.21	0.03	0.24	0.11	S
803	480	Hansa	1094	0.286	0.068	0.24	0.11	S
804	686	Gersuind	415	0.1	0.02	0.12	0.08	S
805	945	Barcelona	306	0.3	0.1	0.24	0.11	S
806	1222	Tina	96	0.17	0.04	0.24	0.11	X
807	4203	Brucato	342	0.07	0.02	0.12	0.08	SC*
901	31	Euphrosyne	2035	0.061	0.015	0.12	0.08	C
902	702	Alauda	1294	0.06	0.01	0.12	0.08	B
903	909	Ulla	26	0.036	0.01	0.12	0.08	P
904	1303	Luthera	163	0.053	0.01	0.12	0.08	C*
905	780	Armenia	40	0.04	0.01	0.12	0.08	M
2001	5	Astraea	6169	0.2694	0.0762	0.24	0.11	S
2002	93	Minerva (516 Gefion)						
2003	110	Lydia	898	0.0731	0.0198	0.12	0.08	X
2004	135	Hertha	15983	0.179	0.032	0.24	0.11	X
2005	159	Aemilia	62	0.064	0.014	0.12	0.08	C
2006	179	Klytaemnestra	513	0.198	0.011	0.24	0.11	S
2007	194	Prokne	379	0.145	0.037	0.2	0.07	C
2008	260	Huberta	26	0.044	0.01	0.12	0.08	P
2009	883	Matterania	169	0.206	0.019	0.24	0.11	S
2010	895	Helio	50	0.071	0.018	0.12	0.08	B
2011	1040	Klumpkea	1815	0.2039	0.1	0.24	0.11	C*
2012	1101	Clematis	17	0.127	0.019	0.2	0.07	C*
2013	1118	Hanskya	116	0.056	0.003	0.12	0.08	C*
2014	1298	Nocturna	186	0.054	0.01	0.12	0.08	X
2015	1338	Duponta	133	0.251	0.04	0.24	0.11	S*
2016	1547	Nele	344	0.355	0.064	0.43	0.08	S
2017	1658	Innes	775	0.0554	0.013	0.12	0.08	A
2018	2076	Levin	1534	0.2015	0.07	0.24	0.11	S
2019	3025	Higson	17	0.074	0.016	0.12	0.08	C
2020	3330	Gantrisch	1178	0.0471	0.012	0.12	0.08	T
2021	3460	Ashkova	59	0.066	0.015	0.12	0.08	C
2022	3561	Devine	19	0.092	0.014	0.12	0.08	C*
2023	3827	Zdenekhorsky	1050	0.074	0.02	0.12	0.08	C*
2024	5026	Martes	481	0.0554	0.013	0.12	0.08	C
2025	5651	Traversa	56	0.036	0.001	0.12	0.08	D
2026	5931	Zhvanetskij	23	0.053	0.007	0.12	0.08	C*
2027	6124	Mecklenburg	78	0.067	0.011	0.12	0.08	C*
2028	6355	Univermoscow	13	0.065	0.02	0.12	0.08	Xt
2029	6769	Brokoff	58	0.068	0.01	0.12	0.08	C*

Number	Parent	Name	Count	Albedo	Err	G	Err	Class
2030	7605	Cindygraber	19	0.029	0.001	0.12	0.08	C*
2031	7744	1986 QA1	98	0.229	0.031	0.24	0.11	S
2032	8060	Anius	31	0.059	0.013	0.12	0.08	C*
2033	8737	Takehiro	57	0.085	0.012	0.12	0.08	C*
2034	10369	Sinden	24	0.062	0.01	0.12	0.08	SC*
2035	10654	Bontekoe	13	0.08	0.015	0.12	0.08	C*
2036	10955	Harig	918	0.057	0.02	0.12	0.08	C*
2037	11097	1994 UD1	33	0.089	0.011	0.12	0.08	C*
2038	11882	1990 RA3	87	0.372	0.191	0.3	0.1	Xe*
2039	12739	1992 DY7	298	0.258	0.04	0.24	0.11	S*
2040	13314	1998 RH71	241	0.056	0.003	0.12	0.08	C
2041	14916	1933 VV7	17	0.133	0.027	0.2	0.07	S*
2042	16286	4057 P-L	94	0.249	0.07	0.24	0.11	S*
2043	17392	1981 EY40	96	0.1	0.05	0.12	0.08	SC*
2044	17492	Hippasos	7	0.066	0.008	0.12	0.08	C*
2045	18466	1995 SU37	257	0.057	0.02	0.12	0.08	C*
2046	21344	1997 EM	75	0.143	0.04	0.2	0.07	S*
2047	21885	1999 UY27	61	0.039	0.006	0.12	0.08	C*
2048	22805	2000 AA169	20	0.086	0.019	0.12	0.08	C*
2049	23255	2000 YD17	12	0.188	0.021	0.2	0.07	S*
2050	29841	1999 FO14	65	0.1	0.05	0.12	0.08	SC*
2051	31811	1999 NA41	144	0.063	0.014	0.12	0.08	C*
2052	32418	2000 RD33	81	0.057	0.02	0.12	0.08	C*
2053	40134	Marsili	16	0.199	0.082	0.24	0.11	S*
2054	43176	1999 XM196	75	0.057	0.02	0.12	0.08	C*
2055	45637	2000 EW12	20	0.057	0.02	0.12	0.08	C*
2056	58892	1998 HP148	20	0.048	0.009	0.12	0.08	C*
2057	69559	1997 UG5	17	0.044	0.007	0.12	0.08	C
2058	116763	2004 EW7	24	0.148	0.129	0.2	0.07	S*
2059	222861	2002 EZ134	11	0.087	0.019	0.12	0.08	C*
2060	291316	2006 BE167	9	0.07	0.014	0.12	0.08	C*
9101	0	NEA	0	0.2	0.07	0.24	0.11	S*
9102	0	Hungaria	0	0.2	0.07	0.24	0.11	S*
9103	0	Mars-crosser	0	0.2	0.07	0.24	0.11	S*
9104	0	MB-inner	0	0.2	0.07	0.24	0.11	S*
9105	0	MB-middle	0	0.1	0.05	0.2	0.07	C*
9106	0	MB-outer	0	0.057	0.02	0.12	0.08	C*
9107	0	Hilda	0	0.057	0.02	0.12	0.08	P*
9108	0	Centaur	0	0.057	0.02	0.12	0.08	C*
9109	0	KBO/TNO	0	0.1	0.05	0.12	0.08	C*
9201	0	Trojan – Mars	0	0.2	0.08	0.2	0.07	S*
9202	0	Trojan – Jupiter	0	0.057	0.02	0.12	0.08	C*
9203	0	Trojan – Saturn	0	0.057	0.02	0.12	0.08	C*
9204	0	Trojan – Uranus	0	0.057	0.02	0.12	0.08	C*
9205	0	Trojan – Neptune	0	0.057	0.02	0.12	0.08	C*
9301	0	Comet-like Orbit	0	0.057	0.02	0.12	0.08	C*

Number	Parent	Name	Count	Albedo	Err	G	Err	Class
9302	0	Comet	0	0.057	0.02	0.12	0.08	C*
9401	0	NEA-Comet	0	0.057	0.02	0.12	0.08	C*
9402	0	MB inner comet	0	0.057	0.02	0.12	0.08	C*
9403	0	MB middle comet	0	0.057	0.02	0.12	0.08	C*
9404	0	MB outer comet*	0	0.057	0.02	0.12	0.08	C*
9405	0	Centaur Comet*	0	0.057	0.02	0.12	0.08	C*
9501	0	Hyperbolic object	0	0.057	0.02	0.12	0.08	C*
9502	0	Planet Satellite	0	0.2	0.1	0.24	0.11	C*

Table 3.1.2.2. The dynamic families and orbital groups used in the LCDB. The Albedo and G columns are the default values used when actual values are not available. A class followed by * is the default based on orbital location using osculating elements.

Table 3.1.2.3 gives the ***osculating*** orbital elements ranges for the broad groups with family numbers > 9000. For each core element (*a*, *e*, *i*), the two columns represent the minimum and maximum values. *Q* is aphelion distance and *q* is perihelion distance.

Family	*a*		*e*		*i*		Class	Albedo	G	Note
9101	q < 1.3						S	0.20	0.24	
9102	1.78	2.0		0.18	16	34	ES	0.3	0.30	1
9103	1.3 < *q* < 1.668		*Q* < 5				S	0.20	0.24	2
9104		2.6					S	0.20	0.24	
9105	2.6	2.7					SC	0.10	0.15	
9106	2.7	5.0					C	0.057	0.12	
9107	3.7	4.2	0.07	0.3		20	P	0.057	0.12	
9108	5.5	30					C	0.057	0.12	
9109	30						C	0.1	0.2	
9201	elements similar to Mars						S	0.20	0.24	3
9202	5.0	5.4					C	0.057	0.12	
9203	elements similar to Saturn						C	0.057	0.12	4
9204	elements similar to Uranus						C	0.057	0.12	4
9205	elements similar to Neptune						C	0.057	0.12	
9301	Q > 5.0						C	0.057	0.12	5
9302	exhibits coma and/or tail						C	0.057	0.12	
9401-9405										
Comets in the orbital space of respectively, NEA, Main belt inner/middle/outer, and Centaurs							C	0.057	0.12	
9501	$e \geq 1.0$						C	0.057	0.12	
9502	Planetary satellite						C	0.057	0.12	

Table 3.1.2.3. The orbital parameters for the broad orbital groups used to classify objects that are not family members.

Notes for Table 3.1.2.3

1 p_V = 0.3 is a compromise value when no taxonomic information is available, since the Hungarias are both a family (common parent, E/X class, p_V = 0.4) and group (similar orbits, S class, p_V = 0.20).

2 Generally, there are no inclination limits on Mars-crossers.

3 The default p_V = 0.20 ± 0.07 for S-type objects was derived from the geometric mean of all S-type objects in the LCDB with known albedos (usually SIMPS).

4 None known and not likely to be found due to perturbations by the other gas giants.

5 Barring any other classification that meets the Q > 5.0 requirement, the orbit is considered "comet like."

3.1.2.1 CAVE USOR – USER BEWARE

We wish to make it clear as possible that an object being in the same orbital space defined for a family does not necessarily make it a member of that family but, instead, that it could be a dynamic interloper. The Hungaria family is just one example where there are numerous interlopers.

The true determination of family membership is possible only when its proper elements and taxonomic spectrum (not just broad taxonomic class) closely match those of a known family parent. The assignments in the LCDB are meant to be good starting points and may be useful in many cases but they are *not* the final word for critical studies.

A Case in Point

For some time, 93 Minerva was considered the main (namesake) body for the Minerva family. Spectroscopic observations showed that it was actually an interloper among what is now called the Gefion family (after 1272 Gefion). What distinguishes the Gefion members is their higher than usual albedo for outer main-belt objects (p_V ~ 0.25) instead of the more typical p_V ~ 0.06.

The AstDys families list has only the Minerva group, which has relatively few members common to the *Nesvorny* Gefion family (516). The Nesvorny Gefion family is used in the LCDB. Members of the AstDys list not in the Nesvorny list were placed in the catch-all outer main-belt group (9106). However, they were not all set to use the defaults of class = C*, G = 0.12 ± 0.08, and albedo = 0.057.

Where available, WISE, AKARI, and/or SIMPS albedos for an object were averaged and that value was assigned with the 'L' (details record) flag. Based on Table 1, objects with albedos < 0.12 were set to type "C*." Type "SC*" was assigned to objects within 0.12 ≤ p_V ≤ 0.18 but the averaged albedo was used in lieu of the default of p_V = 0.1. Objects with pV > 0.18 were assigned the "S*" class. These somewhat arbitrary assignments should reinforce that the albedos in the LCDB are not the final word.

Another Case in Point

While there are some specific families within the common orbital space for the near-Earth asteroids, Hildas, Jupiter trojans, Centaurs, and TNO/KBO objects, in general these groups are treated without distinction between family and group members since there is no single parent body for each group.

For example, when searching the MPCORB file using the osculating elements limits for group 9107 (Hilda space in Table 3), a total of 4615 objects were found. However, looking deeper, 409 of those objects were in families or subfamilies defined by *Nesvorny* and/or AstDys other than the Hildas (e.g., Nesvorny 002, Schubart; AstDys 2022, Devine; AstDys 2027, Mecklenburg).

The 2021 April snapshot of the LCDB summary table found 1484 objects, regardless of U rating, within the orbital space in Table 3 (the previous method of assigning membership to the Hildas). Of those, 258 were assigned to “outsider” families such as those in the previous paragraph.

These are just some of the many examples of the indefinite definition of asteroid families and the possibility for numerous interlopers with “outlying” values in a presumed family. If trying to do critical studies based on true *family* membership, the LCDB should be considered a starting point but *not* the final destination.

“Cave Usor!”

3.1.3 SYNODIC VERSUS SIDEREAL PERIOD

The synodic period depends on viewing aspect and the rate of motion of the asteroid across the sky. An expression for the magnitude of the expected difference between the sidereal period and synodic period based on the phase angle bisector (PAB; see Harris et al., 1984) is

DeltaP = [d(PAB)/dt] * P^2

where	DeltaP	difference between synodic and sidereal periods, in units of the rotation period (usually hours).
	[d(PAB)/dt]	angular rate of change in the Phase Angle Bisector in inverse units of the rotation period, e.g., in units of cycles/hour
	P	the synodic rotation period of the asteroid in the same units of time e.g., hours/cycle

For example, assume an asteroid with a rotation period of 8 hours observed when the PAB is changing by 0.05 deg/day (typical for a main-belt asteroid at opposition). The sidereal-synodic difference is

DeltaP = [0.05 / 360.0 / 24.0] * (8 ^ 2)
= 0.00037 hr.

The synodic-sidereal difference can be either positive or negative, and can exceed the value given by this expression for near-polar aspects, but the expression gives a reasonable estimate of the magnitude of the expected difference.

In most cases, the period given in the summary and details lines is synodic and not sidereal. An 'S' flag (see notes below) indicates that the period is sidereal. There are many entries in both tables that do not carry the 'S' flag when they should. This is part of the legacy nature of the data after converting the files to the new data base, i.e., the old format did not allow for indicating the period was one type or another. We hope to update these and other legacy values that now have qualifying flags in future versions.

For most studies, the difference between sidereal and synodic period is not significant.

3.1.4 INDIRECT DATA

Indirect data are those obtained by calculation and/or assumption.

Diameter, H, and albedo (p_V, p_R, etc.)

The relationship between H, diameter, and albedo is:

D = (1329km) * 10.0^(-0.2*H) / sqrt(albedo)
or
logD (km) = 3.1235 - 0.2H - (0.5 * log(albedo)).

The value of H is usually known, though not always accurately, based on photometric observations. If direct data are available for D and/or p_V, then the above relationships can be used to derive a missing quantity.

Data from the SIMPS study (Tedesco et al., 2004). NASA Planetary Data System) are used when available and no overriding data are available. If a newer value of H than that used by SIMPS is available, the diameter and albedo are re-computed based on Harris and Harris (1997).

If the diameter was based on an assumed albedo and H is revised, the albedo is held constant and the diameter re-computed using the above formulae.

If the diameter was determined by radar, resolved imagery, etc. and a new H is available, the diameter is held constant and the albedo is re-computed.

We acknowledge that several, newer IR surveys (e.g., WISE, AKARI, and Spitzer) have reported diameters. It was an impossible task to weigh the individual results and adopt one for the summary record. Therefore, the SIMPS diameters are still used. However, the lc_details and lc_diameters tables both list all included reported diameters. These allow the user to decide for himself which diameter is the "true" value.

Color Index applied to H

Color index is not generally assumed or entered into the LCDB. However, sometimes the value of H was found in a photometric band other than V, e.g., Cousins R. In that case, and if the value is used to override the H given by SIMPS or the MPCORB table (Minor Planet Center) in the summary record, H is transformed to the V band. When the color index is not directly available, these values are used to transform the measured H value:

V-R 0.45 B-V 0.80 V-SR 0.22

The V-R and B-V values are based on averages in the LCDB, allowing for asteroids generally being redder than the solar color. The V-SR is based on

$(SG\text{-}SR)_{SUN}$ 0.44 (Rodgers et al., 2006)

$V = SR + 0.44(SG\text{-}SR)$ (Fukugita et al., 1996)
$= 0.1936$

When such a transform is used in the summary record, whether or not based on an assumed value, the H value has the 'T' (transformed) flag.

3.2.0 ORPHAN RECORDS

The full summary (MySQL) table contains almost 300,000 "orphaned" records. These are where no lightcurve observations have been reported but other data stored in the details and/or other tables in the LCDB have, e.g., diameters, color index, taxonomic class, etc. These records, and any details records associated with the object, are -not- considered when creating the lc_summary and lc_details tables.

However, the orphan flag ('O') -is ignored- when generating the other tables so that the non-lightcurve data can still be made available.

See also section 6.0.1 ORPHAN RECORDS

4.0.0 LCDB FILE DESCRIPTIONS

The following sections describe the specific tables that are part of the LCDB release. A column map is provided for each table that shows the type and format of each field. These are provided for those who want to convert the CSV files in the PDS4 distribution to fixed-width columnar presentation.

N.B. Again, the format indicates the *maximum* precision allowed in data entry but *not* necessarily the original precision. The latter is retained during LCDB data entry.

Sub-sections describe the meaning of the flags that qualify various fields in each table.

The use of these maps will allow creating custom tables that are more user-friendly than CSV files.

4.1.0 LC_SUMMMARY AND LC_DETAILS TABLES

These are the primary tables in the LCDB release. They show both direct and indirect data, the most important being the direct data of lightcurve period and amplitude, along with our assessment of the quality of the period solution.

The latter is expressed by the U code, which is described in detail below.

The lc_summary table uses one line per object, which includes the full summary listing for the asteroid. This line represents our best determination of the primary information for the given object based on the data in the details table.

For example, where several periods are available, the summary line gives the one that we consider the most likely to be correct. Sometimes that value may be an average of the available values.

In the lc_details table, each line includes core summary information followed by the details record data. There can be multiple lines per asteroid. Each line includes the "Short Reference" that can be used to find the full citation for the original publication in the lc_references table.

4.1.1 MULTIPLE DETAILS TABLE ENTRIES

In some cases, there is more than one detail line under a given asteroid with the same publication reference. This is deliberate in order to allow statistical studies of lightcurve amplitude versus phase versus class (albedo).

For example, if a single publication reports the lightcurve behavior for an asteroid where the synodic period and/or amplitude of the curve changed significantly during the course of the observations, the lc_details table will include an appropriate number of entries. Those entries will "split out" the results so that the period and/or amplitude can be tied to a specific (though maybe only approximate) set of PAB or Phase values. A good example would be a paper reporting the observations of an NEA asteroid over several weeks where the amplitude of the curve when from 1.1 to 0.3 magnitudes over the range of observations.

In most cases, splitting the results into distinct sets was not difficult, e.g., the asteroid was observed on one night at one-week intervals. In some cases, the split was not so distinct. In this case, compromises were made in order to avoid having an excess of multiple entries while still retaining sufficient resolution of the variations versus time.

A variation on the above is if the author(s) forced the data from several blocks of dates to fit a fixed period solution. Here, the period will be the same for all entries, though the amplitude may change. In this case, the period is left blank for the second and subsequent lines. The U code is assigned for each lightcurve based on the presumption that the fixed period is correct, i.e., it is based on the quality of the fit of the data to the presumed period. The main point of interest is the amplitude for the reasons given above. Other information that was derived based on the given block of data, e.g., a value for H, G, or a color index, will be included within that details record as well so that it's clear which block of data was used to derive the given values.

4.1.2 U (QUALITY) CODE

The U code provides our assessment of the quality of the period solution, not necessarily of the data per se. The uniqueness of the solution, while an important factor, is not the sole consideration in making an assessment. The quality of the data is sometimes used as a tie-breaker when deciding between two half-steps, e.g., between 2+ and 3-.

Depending on the specifics for a given asteroid, a good period solution can be obtained by using a large amount of lesser quality data about as well as using less data that is of higher quality. Many factors come into play making the assessment. The table below gives the general outline of the criteria used, going from highest to lowest rating.

3 The lightcurve is completely unambiguous in terms of period, i.e., there are no cycle ambiguities or possible solutions with single, triple, or other number of extrema. The coverage of the entire rotation phase is to the degree than any remaining small gaps can be confidently interpolated.

3– A unique period determination, but possibly some moderate gaps in coverage, enough so that interpolation of the entire curve is not certain, but not enough to allow any other solution.

2+ It is unlikely but not impossible that the period is in error due to cycle counts or alternate numbers of extrema per cycle, and no more than moderate gaps in coverage (as in U = 3-). Another case is if there are indications that a second period (e.g., due to a satellite) might have been overlooked. These can manifest themselves as one or two nights where the data showed an unexpected attenuation compared to the rest of the lightcurve.

2 Result based on less than full coverage, so that the period may be wrong by 30 percent or so *or* to note results where an ambiguity exists as to the number of extrema per cycle or the number of elapsed cycles between lightcurves. Hence the result may be wrong by an integer ratio.

2– Period and total amplitude not firmly established. For example, a single night coverage of about half a cycle including a maximum and minimum, but not enough to derive an accurate period. This is the minimum reliability code that we accept for statistical analysis.

1+ Similar to U = 2-, but with less amplitude so that it is not absolutely certain that the variations are true rotational variation and not due to noise, etc.

1 May be completely wrong. What is interpreted as rotational variation may be just noise, calibration error, etc.

1– Probably wrong. A lightcurve that may be completely wrong (as in U = 1) but, in addition, the claimed period is very unlikely, e.g., a large object with a claim of $P < 2$ h.

0 Result later proven to be incorrect. This appears only in detail table entries, not the summary table.

A possible exception occurs when none of the details lines are U > 2+ but the summary line may have U = 3- or 3. An example would be if one data set in the details table leads to a clearly unique period but has too sparse or too large a gap in coverage to warrant a 3 rating, but another data set densely covers the lightcurve at or very close to the uniquely determined period but the period based on that data set is not necessarily unique. Here, the collective result would rate in the 3 range, but the individual sets would still be in the 2 range.

It is important to keep in mind that U = 0 does not necessarily mean that the data for a given lightcurve are of low quality. The only interpretation that should be inferred is that the *reported solution* has been determined, perhaps from subsequent data, to be incorrect so that not even the loose constraints of U = 1 or U = 2 can be used. For the most part, U = 0 will be used very sparingly and the previous U rating (unless 3) will be retained to avoid the false impression that the data are of limited or no use.

N.B. Until the intermediate release in 2008 November, the LCDB also used a value of '4' for the U code, which indicated that a pole solution had been reported. This is no longer the case since, in the past, there have been cases where a 4 was assigned because there was a pole solution given but the best available period solution was no better than 2.

The period solution quality is now independent of any pole solution. A separate "Pole" flag in the summary and details tables is used to indicate that a pole solution has been reported. The lc_spinaxis Table 1ncludes more details and its own quality code assignment.

Assignment of the refined ratings using a + or – is a work in progress as we catch up with almost 30 years of data entry. Therefore, not all U code ratings will match what we would give under current rules and are subject to change.

Some details lines, and even some summary, may not contain a U code rating. This is deliberate and can be for several reasons.

1 The available data do not include a lightcurve, therefore, it is not possible to give a rating to the curve. In some cases, where the results are reported by observers whose standard of work is known to be of sufficient quality, we may assign an interim U code, usually 2, until a lightcurve or the data are available.

2 In the case where several results are published for a given object in the same reference, we will assign a U code rating for the "best" available data and include only new information for that given Details record, e.g., see section 4.1.1, "Multiple Details Table Entries."

3 When the available data do not reasonably define a period or even constrain a range in which the period lies. In addition, the data may not provide any reasonable indication of the amplitude. The details table entry will have only the reference to the work; the period, amplitude, and U code rating will use the default "no data" entries.

The summary line may also have no period and/or amplitude as well as no U code. This occurs when none of the detail records, even if they have some or all of the information, is deemed insufficiently reliable to put in the summary line. This is done to show that there are data available for the object but that they may be of limited use.

4.1.3 LC_SUMMARY AND LC_DETAILS COLUMN MAP

The column positions assume a 1-space delimiter between columns.

See the notes after the lc_details column map regarding the flags used to indicate the source/method used for certain values

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
EntryFlag	A1	9	"*" indicates a vetted new/revised record since the last major release. Other flags are used during the vetting process that will be removed for the annual vetted release.
Name	A30	11-40	Summary: MPC-assigned name, or designation if not named Details: Approximate mid-date of observations
Desig	A20	42-61	MPC primary designation, if assigned
Family	A8	63-70	The orbital group or collisional family
CSource	A1	72	Flag indicating source for taxonomic classification
Class	A10	74-83	The taxonomic class
DiamSource	A1	85	Flag indicating the source for the diameter
DiamFlag	A1	87	Flag (e.g., < or >) that qualifies the diameter
Diam	F8.3	89-96	Adopted Diameter (km)
HSource	A1	98	Flag indicating the source of the H value
H	F6.3	100-105	Adopted absolute magnitude H
HBand	A2	107-108	The photometric band of H
GSource	A1	110	Flag indicating the source of the G value
G	F6.3	112-117	Adopted phase slope parameter (G on H-G system; see 3.1.1)
G1	F6.3	119-124	Adopted phase slope parameter (G1 on HG1,G2; see 3.1.1)
G2	F6.3	126-131	Adopted phase slope parameter (G2 on HG1,G2; see 3.1.1)
AlbSource	A1	133	Flag indicating the source of the albedo value
AlbFlag	A1	135	Flag (e.g., < or >) qualifying the albedo value
Albedo	F6.4	133-142	Adopted Albedo (same band as H)
PFlag	A1	144	Period qualifier
Period	F13.8	146-158	Rotation period, in hours; usually synodic
PDescrip	A15	160-174	Description of period if PFlag = 'D'; e.g., "long"
AmpFlag	A1	176	Amplitude flag, e.g., > or <
AmpMin	F4.2	178-181	Minimum reported amplitude
AmpMax	F4.2	183-186	Maximum reported amplitude
U	A2	188-189	Lightcurve Quality

Notes	A5	191-195	Qualifying flags for record
Binary	A3	197-199	? = Suspected; B = Binary; M = Multiple; blank if none
Pole	A3	201-203	Y/N; Y = Pole position reported in spin axis table
Survey	A5	205-209	Type of Survey if result from large survey programs, e.g., PTF, WTF, Kepler, TESS, PanSTARRS, etc. See Notes below and Section 5
Exnotes	A3	211-213	Y/N; Y = Entry in lc_exnotes table
Private PRI	A3	215-217	Y/N; Y = Unpublished, contact named observer to request details

The Min/Max Amplitude values are based only on detail lines that have a U >= 2- ratings. If the code is empty or U <= 1+, the detail line min/max amplitudes are not considered.

NOTES
The values for H, G, Diameter, and albedo may have been measured, calculated (e.g., Diameter from H and albedo), or assumed. For IR surveys, e.g., WISE, the H value was often assumed based on the value from the MPCORB table or some other source. Another possible case is a value for H determined using an assumed value for G. See Warner et al. (2009) for a more detailed explanation of the source/method flags.

Table 4.1.4.1 Taxonomic Class Source/Method Flags

A	Assumed based on orbital group
L	Taken from a details table entry
S	SMASS (Bus and Binzel, 2002a; 2002b)
T	Tholen (1984)

Table 4.1.4.2 H Method/Source Flags

A	From Lowell ASTORB table
D	Derived from diameter and albedo
E	Estimated
L	Taken from a details table entry
M	From MPCORB table
S	From SIMPS (Tedesco et al., 2004)
T	Transformed (Usually a details entry converted from H_R to H_V)
W	From WISE (Mainzer et al., 2019)

Table 4.1.4.3 H Color Band

This indicates the color band in which the value for H was found

Blank	Johnson V	SR	Sloan r´	GR	GAIA r(ed)
B	Johnson B	SI	Sloan i´	GB	GAIA b(lue)
V	Johnson V	SZ	Sloan z´	H	2MASS H
R	Cousins R	AC	ATLAS c(yan)	I	2MASS I
I	Cousins I	AO	ATLAS o(range)	J	2MASS J
SU	Sloan u´	AT	ATLAS t		
SG	Sloan g´	GG	GAIA G(reen)		

Table 4.1.4.4 G Source Flags (Summary)

A	Assumed
G1G2	Based on H-G12 (no value for G2) or H-G1,G2 (value for G2) system
L	From an entry in the details table
M	From the MPCORB table
P	From Pan-STARRS (Veres et al., 2015)
W	From WISE (Mainzer et al., 2019)

4.1.4.5 G Method Flags (Details)

A	Assumed
C	Calculated
D	Derived
G	Based on H-G12 (no value for G2) or H-G1,G2 (value for G2) system
M	Measured

4.1.4.6 Diameter Qualifier Flags

<	Diameter is a maximum
>	Diameter is a minimum

4.1.4.7 Diameter Source Flags (Summary)

C	Calculated from albedo and H
D	Derived from albedo and H (after using Harris and Harris, 1997)
K	From AKARI (Usui et al., 2011)
L	Taken from a details table entry
S	From SIMPS (Tedesco et al., 2004)
T	Thermal (determined from IR observations)
W	From WISE (Mainzer et al., 2019)

4.1.4.8 Diameter Method Flags (Details)

A	Assumed
C	Calculated
D	Derived from albedo and H (after using Harris and Harris, 1997)
M	Measured (assumed value for empty/blank field)

4.1.4.9 Albedo Source Flags (Summary)

A	Assumed (based on orbital group or taxonomic type)
D	Derived from H and diameter
K	From AKARI (Usui et al., 2011)
L	From a details table entry
S	From SIMPS (Tedesco et al., 2004)
W	From WISE (Mainzer et al., 2019)

4.1.4.10 Albedo Method Flags (Details)

A	Assumed
C	Calculated

D	Derived from albedo and H (after using Harris and Harris, 1997)
M	Measured (assumed value for empty/blank field)

4.1.4.11 Period Flags

<	Period is a maximum value
>	Period is a minimum value
D	Indeterminate period described in the PDescrip field
S	Period is sidereal (default is synodic)

4.1.5 FIELD (FLAG) CODES USED IN SUMMARY AND DETAIL LINES

The flags appear in the data field immediately before the value they qualify. In most cases, they are a single character.

Table 4.1.5.1 AMPFLAG (Amplitude Flag)

Blank	NONE
<	Less than
>	Greater than

PFLAG (Period Flag)

Blank	NONE
<	Less than
>	Greater than
D	No numerical value, see P DESC field description
S	Sidereal period, default is no flag and synodic period
U	Uncertain, not the same as ambiguous where one or additional periods are reported. For example, the data did not allow finding a definite period and so the author(s) reported a "best guess."

NOTES (single letter flag(s))

Blank	NONE
?	Usually tied with 'T' or 'A' flags to indicate uncertainty
–	Tied with T flag. See notes below.
<X>	Number max/min pairs per rotation, e.g., 3 is a trimodal lightcurve.
A	Ambiguous period (see lc_ambiguous table for details)
D	Period determined by us that differs from that given in the original publication
E	Occultation observation (usually when reporting a diameter)
H	Space telescope observations (optical)
I	IR/Thermal observations (e.g., Spitzer)
M	Polarimetric observation
N	No lightcurve published
O	Adaptive optics observation
P	Photographic photometry
R	Radar observation

S Spectroscopic
T Tumbling (NPA rotation - see lc_npa table for details and notes below).
U Undetermined period/amplitude. Used to indicate that data were obtained but no period or amplitude was given, usually because there was no obvious trend. A raw plot of the data may have been included.
V Visual photometry

The 'A' and 'T' notes flags are used to call the reader's attention to the lc_ambiguous or lc_npa tables, respectively. They should not be taken as stand-alone information. Instead, consider them footnote numbers in the body of a main text. The other reports (and original references) are the actual footnotes.

The A flag does not appear in the summary line unless the summary line value itself represents an ambiguous solution, i.e., just because a details line may report an ambiguous period does not mean that the summary period is also ambiguous.

The T flag currently has four possible qualifiers

Blank The asteroid has a PAR < -1, i.e., it is definitely tumbling.

Example: T

? Possible tumbler. There is some evidence that the asteroid might be a tumbler. It may carry a PAR = 0 to -1. See the discussion for the lc_npa table for the meaning of the PAR codes.

Example: T?

0 The tumbling damping time scale (see Pravec et al, 2005) is long enough that tumbling might be expected, but observations are not sufficient to substantiate either tumbling or not tumbling, PAR = 0.

Example: T0

– The tumbling damping time scale is long enough that tumbling might be expected, but observations indicate that the object is NOT tumbling, i.e., PAR >= 1.

Example: T-

+ The tumbling damping time scale is short enough that tumbling would not seem likely, however observations indicate that it may be tumbling or actually is tumbling, i.e., PAR = < 0.

Example: T+

We include the expanded tumbling notes to call attention to what we consider to be an important aspect in the study of YORP spin up/down theories. This is done by making known any asteroids that are or are strongly believed to be tumbling as well as those that should be and aren't or are and shouldn't be.

The W flag is included so that those doing statistical studies can include or exclude the results from these surveys. Such surveys can introduce significant biases by "cherry picking" the best results from a large pool and so skew overall rotational statistics. See the paper by Warner and Harris (2011, Icarus).

4.1.6 DATA SUITABLE FOR ROTATION RATE STUDIES

As noted in Warner et al. (2009), only those objects with a U code of 2- or greater in the lc_summary table, i.e., U = 2-, 2, 2+, 3-, or 3, should be used for rotational rate studies and, unless there is a specific reason otherwise, the summary line period should be used instead of one of the periods in the details table.

4.2.0 LC_AMBIGUOUS (AMBIGUOUS PERIODS)

This Table 1ncludes any record where the notes flag in a summary and/or detail record indicates an ambiguous period.

There is not always a direct cross-connection between the summary and details entries. For example, it's possible to have a summary line without the ambiguous period flag but one or more of the Details lines to have the flag. In this case, we judge that the ambiguity has been resolved by subsequent observations, but retain the ambiguous flag in the detail line for historical accuracy.

In turn, if the summary line is flagged as ambiguous, this does not mean that any of the details lines are also flagged as such. In that case, it means that no one solution sufficiently stands out and so the one that is reported on the summary line is considered to be only the most probable solution.

The first line for a given object is the Summary line, which contains the number and name of the object and the adopted period and amplitude. As noted above, the details lines(s) may not agree with the summary line.

4.2.1 LC_AMBIGUOUS COLUMN MAPPING

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
Name	A30	9-38	MPC-assigned name, or designation if not named

SumPer	F13.8	61-73	Period from summary table, hours
SumAmp	F4.2	75-79	AmpMax from summary table
SumNotes	A5	81-85	Qualifying flags for the summary record
DetNotes	A5	87-91	Qualifying flags for the details record
ShortRef	A30	93-122	Short Reference from lc_references table
DateObs	A10	124-133	Mid-date (yyyy-mm-dd, 0h UT) of observations
Period1	F13.8	135-147	Preferred period, hours, from details record
Period1Err	F13.8	149-161	Error in preferred period, if reported
Amp1	F4.2	163-166	Preferred amplitude from details record
Amp1Err	F4.2	168-171	Error in amplitude, if reported
Period2	F13.8	173-185	First alternate period, hours
Period2Err	F13.8	187-199	Error in period, if reported
Amp2	F4.2	201-204	First alternate amplitude
Amp2Err	F4.2	206-209	Error in amplitude, if reported
Period3	F13.8	211-223	Second alternate period, hours
Period3Err	F13.8	225-237	Error in period, if reported
Amp3	F4.2	239-242	Second alternate amplitude
Amp3Err	F4.2	244-247	Error in amplitude, if reported
Period4	F13.8	249-261	Third alternate period, hours
Period4Err	F13.8	263-275	Error in period, if reported
Amp4	F4.2	277-280	Third alternate amplitude
Amp4Err	F4.2	282-285	Error in amplitude, if reported

4.3.0 LC_BINARY (BINARY/MULTIPLE ASTEROIDS)

This Table 1ncludes those asteroids that are known or suspected binaries. This is not meant to be a comprehensive compilation of data for binary asteroids. Visit the URL given in section 2.2.0 for a page that provides more details as well as links to the original journal articles.

Each line indicates the type of binary. There are four broad categories:

A Fully-asynchronous

Example: 1509 Esclangona The satellite's rotation period is different from its orbital period. In this case, the orbital period is given along with the independent rotation period and lightcurve amplitude of the satellite, if available.

S Singly-asynchronous:

Example: 5905 Johnson. The satellite's rotation period and orbital period are the same, i.e., they are tidally-locked, but different from the primary's spin period. In this case, nly an orbital period is given. The lightcurve may be flat or bowed between events. If flat, the presumption is that the satellite is nearly spheroidal and the rotation is still tidally-locked to the orbit. If the lightcurve shows an overall "bowed" shaped, this is presumed to indicate a significantly elongated satellite.

F Fully-synchronous

Example: Pluto/Charon, 90 Antiope. The rotation period of the primary and satellite are the same and is the same as the orbital period of the satellite. In this case, the primary rotation period and lightcurve amplitude is given and matches the orbital period of the two bodies. No secondary period is given.

U Undetermined

This is usually reserved for binaries discovered by imaging with Hubble or very large ground-based telescopes. In most cases, the orbital parameters are not or very poorly known and there are no lightcurves to determine the actual type of binary, e.g., if the satellite is tidally locked to its orbital period.

In some asynchronous systems, it is not always possible to determine with certainty which of the two periods is due to the primary and which is due to secondary. In these cases, we are forced to give the period and amplitude of one body as that of the "primary" and the other period and amplitude as that of the "secondary" when, in fact, the roles may be reversed from our selection.

For multiple systems and in _most_ cases, the satellite information is for the first one discovered. In some cases, e.g., 3749 Balam, the first discovery was for a satellite with a long orbital period of 1920 hours. It is assumed that the satellite's rotation is not equal to the orbital period. A second satellite was found that has a rotation period that is tidally-locked to its orbital period of about 33.4 hours.

Each line also gives the primary rotation period and amplitude and secondary/orbital periods/amplitudes as appropriate. If available, the estimated effective diameter ratio (Ds/Dp) is given, as are the ratio of the semi-major axis of the satellite orbit to the diameter of the primary (A/Dp).

The Ds/Dp ratio is a minimum in most cases since total eclipses were not seen in the satellite's lightcurve. The DsDpFlag qualifies this value, e.g., < or >. If there is no flag and there is a Ds/Dp value, assume '='.

4.3.1 SECONDARY VS. ORBITAL PERIOD

In some cases, there is only a secondary period ("SecPer") given; in others, only an orbital period ("OrbPer"); and in others, both periods are given. The case when "PerOrb" is given is usually the result of timing of mutual events (occultations and/or eclipses) and so there will be at least an "EventMax" value given.

When only "SecPer" is reported, then the lightcurve was defined by two periods, with the second period attributed to the rotation of a satellite but the viewing geometry did not allow mutual events. The second period might also be due to low-level tumbling. Regardless, without mutual events or other definitive confirmation, the asteroid will likely be classified as "suspected" and not confirmed.

When both periods are reported, then the secondary period is likely due to the presence of a third body in the system. Unless separate mutual events or other definitive evidence is provided, they system will be classified as "binary" and not "multiple."

4.3.2 LC_BINARY COLUMN MAPPING

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
Name	A30	9-38	MPC-assigned name, or designation if not named
SumBin	A1	40	? = suspected; B = binary; M = multiple
SumPer	F13.8	42-54	Period from summary table, hours
SumAmp	F4.2	56-59	AmpMax from summary table
ShortRef	A30	61-90	Short reference from lc_references table
DateObs	A10	92-101	Mid-date (yyyy-mm-dd, 0h UT) of observations
DetBin	A1	103	? = suspected; B = binary; M = multiple
BinType	A1	105	A = fully-asynchronous; S = singly-asynchronous; F = fully-synchronous
PrimPer	F13.8	107-119	Rotation period of the primary, hours
PrimPerErr	F13.8	121-133	Error in period, if reported

PrimAmp	F4.2	135-138	Maximum amplitude of the primary lightcurve
PrimAmpErr	F4.2	140-143	Error in primary amplitude, if reported
SecPer	F13.8	145-157	Secondary period (see section above)
SecPerErr	F13.8	159-171	Error in secondary period, if reported
SecAmp	F4.2	173-176	Amplitude of secondary period lightcurve
SecAmpErr	F4.2	178-181	Error in amplitude, if reported
OrbPer	F13.8	183-195	Orbital period of the first satellite, hours
OrbPerErr	F13.8	197-209	Error in period, if reported
EventMin	F4.2	211-214	Shallowest amplitude of the mutual events
EventMax	F4.2	216-219	Deepest amplitude of the mutual events
DsDpFlag	A1	221	Qualifier for Ds/Dp, e.g., < or >
DsDp	F4.2	223-226	Ratio of first satellite/primary effective diameters
DsDpErr	F4.2	228-231	Error in Ds/Dp value
ADp	F5.2	233-237	Ratio of first satellite orbital semi-major axis to primary diameter
ADpErr	F5.2	239-243	Error in Ds/Dp ratio

4.4.0 LC_COLORINDEX

Unless the lc_exnotes Table 1ndicates otherwise, the bands are on the Johnson-Cousins BVRI, Sloan griz, or ATLAS oc systems.

4.4.1 LC_COLORINDEX COLUMN MAPPING

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
Name	A30	9-38	MPC-assigned name, or designation if not named
SumPer	F13.8	40-52	Rotation period from summary table, hours
SumAmp	F4.2	54-57	AmpMax from summary table
ShortRef	A30	59-88	Short reference from the lc_references table
DateObs	A10	90-99	Mid-date (yyyy-mm-dd, 0h UT) of the observations
DetPer	F13.8	101-113	Rotation period from details record, if reported; hours
DetPerErr	F13.8	115-127	Error in rotation period, hours
DetAmp	F4.2	129-132	Lightcurve amplitude, if reported
DetAmpErr	F4.2	134-137	Error in amplitude
BV	F6.3	139-144	B-V color index
BVErr	F6.3	146-151	B-V error
BR	F6.3	153-158	B-R color index

BRErr	F6.3	160-165	B-R error
VR	F6.3	167-172	V-R color index
VRErr	F6.3	174-179	V-R error
VI	F6.3	181-186	V-I color index
VIErr	F6.3	188-193	V-I error
SGR	F6.3	195-200	g-r color index
SGRErr	F6.3	202-207	g-r error
SRI	F6.3	209-214	r-i color index
SRIErr	F6.3	216-221	r-i error
SIZ	F6.3	223-228	i-z color index
SIZErr	F6.3	230-235	i-z error
ATLco	F6.3	237-242	ATLAS c-o color index
ATLcoErr	F6.3	244-249	ATLAS c-o error

4.5.0 LC_DIAMETERS

This Table 1s provided for those wanting a quick way to dissect and compare diameters reported in the summary and details tables. It includes "orphaned" summary records (see Section 3.2.0/6.0.1, "ORPHAN RECORDS").

4.5.1 LC_DIAMETERS COLUMN MAPPING

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
EntryFlag	A1	9	“*” indicates a vetted new/revised record since the last major release. Other flags are used during the vetting process that will be removed for the annual vetted release.
Name	A30	11-40	Summary: MPC-assigned name, or designation if not named Details: Short reference from lc_publications table
Period	F13.8	42-54	Summary: Rotation period summary table, hours Details: N/A
HB	A2	56-57	Summary: Photometric band for adopted H Details: Photometric band for H
H	F6.3	59-63	Summary: Adopted absolute magnitude Details: H used in given source
HErr	F6.3	65-70	Summary: N/A Details only: Error in H from given source

G	F6.3	73-78	Summary: Adopted phase slope parameter on H-G system Details: G used in given source
GErr	F6.3	80-85	Details only: G error in given source
G1	F6.3	87-92	Summary: Adopted G1 on HG1(,G)2 system Details: G1 reported in given source
G1Err	F6.3	94-99	Summary: N/A Details: G1 Error in given source
G2	F6.3	101-106	Summary: Adopted G2 on HG1(,G)2 system Details: G2 reported in given source
G2Err	F6.3	108-113	Summary: N/A Details: G2 error in given source
Pv	F6.4	115-120	Summary: Adopted albedo (in HB) Details: Albedo (in HB) in given source
PvErr	F6.4	122-127	Summary: N/A Details: Albedo error in given source
Diam	F8.3	129-136	Summary: Adopted diameter (km) Details: Diameter reported in given source
DiamErr	F8.3	138-145	Summary: N/A Details: Diameter error in given source
Notes	A5	147-151	Summary: Qualifying flags for summary record Details: Qualifying flags for details record

4.6.0 LC_FAMILYLOOKUP

The LCDB recognizes more than 200 dynamical families and orbital groups. The list of dynamical families is taken from Nesvorny (2015) and Nesvorny et al. (2015) and the AstDys (2021) web site. Family assignment for individual objects is based on the list of family membership from the AstDys site. When the object is not in the family membership list, it is assigned to a broad orbital group. See "3.1.2 FAMILY/GROUP MEMBERSHIP, DEFAULT ALBEDOS, AND TAXONOIMC CLASS."

4.6.1 LC_FAMILYLOOKUP COLUMN MAPPING

Field	Format	Pos	Notes
Number	A7	1-7	Family number. Values < 1000 are from *Nesvorny* (2015).
Parent	I7	9-15	MPC-assigned number of the parent (largest) body of the of the family. 0 if an orbital group and not a family.
Family Name	A20	17-36	Name of the parent body of the family or the broad orbital group.

Count	I7	38-44	Number of members in a family (from AstDys site list).
Albedo	F6.3	46-51	The default albedo for the family/group.
Err	F6.3	53-58	The estimated error in the albedo.
G	F6.2	60-65	The default value for G (H-G system).
Err	F6.2	67-72	The estimated error for G.
Class	A10	74-83	The default taxonomic class.

If Class is appended with an asterisk, e.g., C*,the value is based on orbital location and not that of the parent body.

4.7.0 LC_EXNOTES

The lc_exnotes table contains extended "free-form" notes for summary and/or details records. These entries allow expanded information that cannot be given by a simple, single-character flag.

In some cases, only the summary record has an extended note for an object. In this case, the output line will include the summary information given in the column mapping but the rest of the fields will have the default <no data> entry.

If there is no summary extended note for a given asteroid but one or more details records with notes, then - for each detail record - the summary number and name are included, the summary notes field uses the default <no data>, and the data for the given detail record are given.

If there are both summary and details extended notes, then the first line includes only the summary extended note and uses the default <no data> for the rest of the line. Subsequent lines for the asteroid do not include the summary note but do include the detail record note.

In short, no line will contain BOTH a summary and detail extended note.

The summary and details table Exnotes fields are defined as varchar(1024) in their MySQL tables. In practice, however, the longest entries is < 128 characters. Even so, keep in mind that a full-length line could exceed 1100 characters.

4.7.1 LC_EXNOTES COLUMN MAPPING

The column mapping below allows for the maximum length of each field. In practice, a delimited (e.g., comma or semi-colon) file with one record per line will be much shorter than the maximum length.

The maps below do not account for the <no data> flags, usually '-' for a string value and -99 for the Number field if the asteroid is not numbered. For a summary note only record, the fields after "SumExnotes" would use the <no data> value. For details note only record, the "Number" and "Name" fields would have values but the "SumExnotes" field would use the <no data> value.

SUMMARY EXTENDED NOTE

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
Name	A30	9-38	MPC-assigned name, or designation if not named
SumExNotes	A1024	40-1063	Extended note for summary record

WITH DETAIL EXTENDED NOTE

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
Name	A30	9-38	MPC-assigned name, or designation if not named
WorkedAs	A20	40-59	The name or designation used by the original authors. This may or may not be the same as the current MPC-assigned name and/or designation
ShortRef	A30	61-90	The short reference in the publications table
DetExNotes	A1024	92-1115	Extended note for detail record

4.8.0 LC_NPA (NON-PRINCIPAL AXIS ROTATION - TUMBLING)

This table not just confirmed tumbling asteroids but those that are suspected, those that "should be" tumbling but apparently are not, and those that are tumbling that "should not be" tumbling.

In the table, the first period (DetPeriod) is usually the dominant one. Whether or not it is the period of rotation or precession cannot often be established.

4.8.1 PAR RATING

The PAR rating is adopted from Pravec et al. (2005). See also Pravec et al. (2010), in which a revised set of damping times is developed. These so-called "short" damping times are several times shorter than in the original paper and are preferred.

Here is a brief description of the PAR codes. Pravec et al. for a more detailed explanation.

-4	Physical model of the NPA rotation constructed
-3	NPA rotation reliably detected with the two periods resolved. There may be some ambiguities in one or both periods.
-2	NPA rotation detected based on deviations from a single period but the second period is not resolved.
-1	NPA rotation possible, i.e., deviations from a single period are seen, but not conclusively.

0	Insufficient data to determine if rotation is PA or NPA
+1	PA rotation is consistent with the data but coverage is insufficient.
+2	PA rotation likely, or deviations from PA are small with some overlapping data fitting a PA rotation period.
+3	PA rotation quite likely
+4	PA spin vector obtained.

Entries with a positive number are rare and used when the asteroid was thought to be tumbling but further examination showed it was likely in PA rotation, or when the damping time to PA rotation is sufficiently long that the given asteroid would more likely be in NPA than PA rotation.

4.8.2 LC_NPA COLUMN MAPPING

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
Name	A30	9-38	MPC-assigned name, or designation if not named
SumPer	F13.8	40-52	Rotation period from summary record, hours
SumAmp	F4.2	54-57	Maximum lightcurve amplitude from the summary record
SumNotes	A5	59-63	Qualifying flags for the summary record (See Notes section after lc_details)
ShortRef	A30	65-94	Short reference from the lc_references table
DateObs	A10	96-105	Mid-date (yyyy-mm-dd, 0h UT) of observations
DetPeriod	F13.8	107-119	First (dominant) period from the details record, hours
DetPerErr	F13.8	121-133	Error in period
DetAmp	F4.2	135-138	Amplitude associated with first period
DetAmpErr	F4.2	140-143	Error in amplitude
DetPer2	F13.8	145-157	Second period, either precession or rotation, hours
DetPer2Err	F13.8	159-171	Error in second period
DetAmp2	F4.2	173-176	Amplitude associated with second period, rarely reported
DetAmp2Err	F4.2	178-181	Error in amplitude
PAR	A2	183-184	PAR rating under Pravec et al. system
DetNotes	A5	186-190	Qualifying flags for the details record (See Notes section after lc_details)

4.9.0 LC_REFERENCES (REFERENCES PUBLICATIONS)

The LC_REFERENCES table contains the Bibcode, short reference, and literature citation for each reference in the other data tables. The literature citation limits the number of authors to five. If there are more than five, the fifth "author" is "et al." In recent years, some journals stopped using page numbers but article ids. These are shown as "Axx" with xx being the article id. Where page numbers are given, both starting and ending numbers are given.

As is customary, if there is only one publication for a given author in a given year, the short reference does not include a letter after the year, e.g., Warner (2018). If there is more than one publication, then the entries are appended with 'a' through 'z'. So far, it has not been necessary to devise a method for someone having more than 26 publications in a single year.

Some short references are appended with 'web', e.g., Warner (2018web). This indicates the results were posted on a web site, hopefully in anticipation of publication in a permanent journal. This also prevents a conflict should an author publish at least 23 papers ('w') -and- also posted pending results on a web site.

Current Bibcodes are 19 characters long. The field allows one more character should expansion be required in the future. For the time being, the current table does -not- pad the Bibcode to 20 characters.

The Citation field allows up to 255 characters. However, since the LCDB limits the list to five authors, the likelihood of this field exceeding 80 characters is very small.

4.9.1 LC_REF COLUMN MAPPING

Field	Format	Pos	Notes
BibCode	A20	1-19	19-character BibCode
ShortRef	A30	21-50	Primary author and year, e.g., Warner (2018a)
Citation	A255	52-306	Literature citation

N.B. Initials for names are packed, e.g., Warner, B.D. and not Warner, B. D.

4.10.0 LC_SPINAXIS (POLE SOLUTIONS)

This Table 1ncludes any asteroid for which spin axis information has been reported. See section 2.1.1, "Spin Axis Catalogs" for additional resources and references.

The table lists up to four pole solutions. This allows for the known issues with lightcurve inversion, especially when the object has a low orbital inclination. Generally, it's not uncommon to have two solutions that differ by 180° in longitude but have nearly the same latitude. However, there are other cases where the latitudes are mirrored about the equator and the longitudes are similar. There is also the possibility that both longitude and latitude are mirrored, thus having four possible solutions.

4.10.1 Q (QUALITY) RATING

The Q value gives our assessment of the quality of the pole solution. It is adopted from the rating system used in Kryszczynska et al. (2007, *Icarus* **192**, 223-237).

0 Either wrong or very uncertain determination

1 Possible but not certain pole determination. This will most often appear when a limited number of data sets is used, especially if methods other than lightcurve inversion are involved.

2 Good determination, based on large dataset. The solution consists of one or two solutions (and possibly their 180° mirrors). If two solutions, they may differ in both longitude and latitude but not by the simple 180° mirror.

3 Very good determination, based on large dataset, an ambiguity of about 180° in pole longitude might appear.

4 Excellent determination, pole position confirmed by methods based on independent datasets (for example, lightcurves and radar data, lightcurves and spacecraft fly-by).

P A prograde rotation has been determined but no specific pole position has been determined. This will be followed by a 0 or 1, indicating the quality of the determination.

R A retrograde rotation has been determined by no specific pole position has been determined. This will be followed by a 0 or 1, indicating the quality of the determination.

If the Q value is blank, the given pole solution has not yet been reviewed under the new rating system.

4.10.2 SPECIAL ENTRIES

Sometimes an entry will have a value of L1 = -1. This indicates no longitude was reported. The value of B1 has two interpretations

If the latitude is -99.9, then no latitude was reported. This entry must have a Q value of P or R, meaning prograde or retrograde rotation was determined. This is usually by seeing how the synodic rotation period changed before, at, and after opposition. Other techniques than lightcurve inversion can also produce a sense of rotation but no longitude/latitude pair.

If the latitude is $|\beta| <= 90.0$, then a latitude only solution was found, although it is usually more a "best guess" and can have substantial errors. Again, the Q rating must be P or R, which is assigned on the basis that positive latitudes imply prograde rotation and negative latitudes imply retrograde rotation.

A negative longitude will not appear for Long2-Long4.

4.10.3 LC_SPINAXIS COLUMN MAPPING

Field	Format	Pos	Notes
Number	I7	1-7	MPC-assigned number; empty if no number assigned
Name	A30	9-38	MPC-assigned name, or designation if not named
SumPer	F13.8	40-52	Rotation period from summary record, hours
SumAmp	F4.2	54-57	Maximum lightcurve amplitude from the summary record
ShortRef	A30	59-88	Short reference from lc_references table
DateObs	A10	90-99	Mid-date (yyyy-mm-dd, 0h UT) of observations
Long1	F5.1	101-105	Ecliptic longitude of the preferred pole
Long1Err	F5.1	107-111	Error in Long1
Lat1	F5.1	113-117	Ecliptic latitude of the preferred pole (always includes + or -)
Lat1Err	F5.1	119-123	Error in Lat1
Long2	F5.1	101-105	Ecliptic longitude of first alternate pole
Long2Err	F5.1	107-111	Error in Long2
Lat2	F5.1	113-117	Ecliptic latitude of first alternate pole (always includes ±)
Lat2Err	F5.1	119-123	Error in Lat2
Long3	F5.1	101-105	Ecliptic longitude of second alternate pole
Long3Err	F5.1	107-111	Error in Long3
Lat3	F5.1	113-117	Ecliptic latitude of second alternate pole (always includes ±)
Lat3Err	F5.1	119-123	Error in Lat3
Long4	F5.1	101-105	Ecliptic longitude of third alternate pole
Long4Err	F5.1	107-111	Error in Long4
Lat4	F5.1	113-117	Ecliptic latitude of third alternate pole (always includes ±)
Lat4Err	F5.1	119-123	Error in Lat4
SidPer	F13.8	125-137	Sidereal period of spin axis solution (for long/lat1)
Model	A1	139	Y/N; Y = Shape model reported.
Q	A4	141-144	Quality of pole solution (see section 4.10.1)

5.0.0 HANDLING SURVEY DATA

5.0.1 INTRODUCTION

Up until the 2020 February release, the LCDB contained two fields related to large surveys: WideField and SparseData. Due to the coming of surveys that far exceed the data/results density of earlier works, and the desire to qualify the results from lightcurve inversion programs using dense and/or sparse data, the two fields were merged into a single field: "Survey", which is up to five alphanumeric characters long.

The previous discussions on wide-field and sparse data sets below have been modified to include the revised and new definitions. To understand the foundation for the differentiation between dense lightcurves and among the various surveys, you are referred to two papers:

> Warner, B.D., Harris, A.W. (2011) "Using sparse photometric data sets for asteroid lightcurve studies." Icarus 216, 610-624.
>
> Harris, A.W., Pravec, P., Warner, B.D. (2012) "Looking a gift horse in the mouth: Evaluation of wide-field asteroid photometric surveys." Icarus 221, 226-235.

In essence, the reason for categorization is because of the large biases introduced into rotational study statistics by the surveys because they do not analyze and report results on _every_ object observed, but small, select data sets, those where there was at least some success in arriving at "reliable" results.

For example, in Waszczak et al. (2015), they reported observations on more than 50,000 asteroids but found less than 10,000 "reliable" periods, or about a 16% success rate. Chang et al. (2015) had about a 27% success rate. As a result, statistical studies should use most survey data with some caution, if at all, since those data sets have the potential for adding substantial biases, e.g., those against super-fast or super-slow rotators, tumblers, binary objects, and, probably most significantly, against objects with low amplitudes, i.e., A < ~0.10-0.12 mag.

Because of the large amounts of lightcurve results reaching the literature, the LCDB authors adopted the policy of assigning U = 2 to any lightcurve from most survey data sets where the authors claimed a "reliable" period and then flagging the entry so that end-users can decided whether or not to include the results in their research.

When the authors of a paper reported periods that were not considered reliable, those results were assigned U = 1 in the LCDB. Where no period was reported, what information that was available, e.g., amplitude, was entered and no U code was assigned.

Some surveys have provided the phased lightcurve plots, e.g., Waszczak et al., Erasmus, and Pal et al. Over time, we hope to review those plots and assign more accurate assessments. Even so, the results will still be flagged such that they are not included in the BASIC DATA set.

As with almost any attempt to put objects into narrow categories, there are gaps and overlaps. Even so, the authors offer the following categories and samples of what data falls into each one.

5.1.0 WIDE-FIELD SURVEYS

5.1.1 SPARSE WIDE-FIELD

Summary/Details Listing Code: SWF
Included in BASIC DATA: NO

Definition: Data from a survey that gets a relatively small number of data points over a limited number of nights without regard to extending observations as needed to remove ambiguities or obtain a more accurate view of the period and/or nature (binary, tumbling) of the asteroid.

Examples: Palomar/Zwicky Transient Factory, TALCS, some K2

5.1.2 DENSE WIDE-FIELD

Summary/Details Listing Code: DWF
Included in BASIC DATA: NO

Definition: Data from a survey that gets a large number of data points over an extended period of time. Usually this is possible only for surveys using space-based telescopes. In these surveys, long-period objects are often better covered and defined than by ground-based surveys or programs. However, as with most other surveys, there is a significant possibility for analysis to be misled because of fixed observing cadences. For example, if a survey takes a image every 30 minutes and the rotation period of an object is almost exactly a half-integral multiple of 30 minutes, then the sampling is capturing nearly the same point on the true lightcurve at each interval.

Examples: TESS, some K2

5.2.0 SPARSE DATA SETS

5.2.1 WIDE-FIELD OR ALL-SKY

Summary/Details Listing Code: SD
Included in BASIC DATA: NO

Definition: These are generally the result of surveys such as the Catalina Sky Survey, i.e., 2-5 data points a night on a few nights each lunation over several years. A more extensive example is the Lowell Lightcurve Database (Bowell et al., 2014) that includes hundreds of observations for some asteroid over 10-15 years. The Gaia DR2 data set is the most extensive one to-date.

It's usually only if using them in lightcurve inversion modeling that these data sets are used for period analysis and rarely, if at all, as stand-alone sets.

Examples: Catalina Sky Survey, Lowell, Pan-STARRS, Gaia DR2, ATLAS

5.2.2 NARROW/FIXED FIELD

Summary/Details Listing Code: SD
Included in BASIC DATA: NO

Definition: Data from a project that took repeated images of fixed intervals of a fixed field for a single night and, possibly, on a second night an adjacent field that accounted for average sky motion of the intended targets. The data sets can be used stand-alone for period analysis but the results can be suspect, at best.

Examples: Dermawan et al. (2011)

5.3.0 LIGHTCURVE-INVERSION

Lightcurve inversion (see Kaasalainen and Torppa (2001) and Kaasalainen et al. (2011) uses dense and/or sparse data to try to find a model for an asteroid that will generate a lightcurve that reproduces the actual data on more than one date.

Unless specific lightcurves are published (not just model/data comparisons), the NOTES field in the record will include 'N' (lightcurve not published). If dense lightcurves are involved, it's possible that one or more lightcurves were published under a different author and/or in the same or other journal.

The reported period is almost always sidereal. In this case, the period flag (PFlag) field will get set 'S'. The U rating generally follows the guidelines set on the DAMIT site

https://astro.troja.mff.cuni.cz/projects/damit/asteroids

but the highest rating is still U = 3.

5.3.1 DENSE LIGHTCURVE INVERSION

Summary/Details Listing Code: LCI-D
Included in BASIC DATA: YES

Definition: The modeling relied significantly, but not exclusively, on dense lightcurves (see definition in Warner and Harris, 2011) as well as sparse data.

N.B. Results that are based solely on dense lightcurves are not included in this class and are not flagged in the Survey field.

Example: Hanus et al. (2016)

5.3.2 SPARSE LIGHTCURVE INVERSION

Summary/Details Listing Code: LCI-W
Included in BASIC DATA: NO

Definition: The modeling relied exclusively on sparse data, such as Lowell, Gaia, Catalina, etc.

Example: Durech et al. (2016)

6.0.0 NUMBERS OF INTEREST

The numbers presented here are as of 2021 March 28.

6.0.1 ORPHAN RECORDS

No "orphan" records are in the lc_summary table. These are from publications that did not report any observations towards finding a lightcurve period and/or amplitude. Some examples are most of the IR survey papers (WISE, AKARI, SPITZER) that reported diameter and diameter. Others include those reporting only color indices or taxonomic classification.

Likewise, if a summary record is orphaned, none of its detail lines are reported in the lc_details table. However, the subtables, e.g., lc_binary and lc_colorindex, DO include the details lines for orphaned summary records. In those tables, the number and name of the asteroid from the summary line are included in each record.

6.1.0 SUMMARY TABLE - OVERVIEW

Total Records:	339,325
Non-Orphan:	34,790
Survey:	24,909 (all where data are from a details record from survey)
Survey:	23,585 (all with period from a details record from survey)
Survey:	340 (orphan data, e.g., taxonomic class, from a details record from survey)
U ≥ 1-:	31,429 (non-orphan) *
U ≥ 2-:	29,729 (non-orphan)

* This is the number of entries in the lc_summary table with a period *and* was given a U rating. This excludes summary lines where no period, amplitude, or U code was given. These "no data" lines are included to show that some lightcurve data are available but they were insufficient to make even an approximate guess of the period and/or amplitude.

Pole:	4,387 (could be just "retrograde vs. prograde")
Tumblers:	549
Binaries:	474 / 410 (all/U ≥ 2–, includes suspected) **
Binaries:	357 / 294 (all/U ≥ 2–, 'B' or 'M', i.e., considered confirmed)

** The larger counts for binaries with no U rating restriction include binary or multiple asteroids discovered by adaptive optics, occultation, or spacecraft.

6.1.1 SUMMARY TABLE: U >= 2- ONLY

NEA: 1,714 (total + group 9101)
Binary: 108 (6.3%, includes 'B', 'M', and '?')
Pole: 75 (4.4%)

Hungaria: 675/340/335 (total/*Nesvorny*/group 9102) ***
Binary: 48 (7.1%, includes 'B', 'M', and '?')
Pole: 65 (9.6%)

Hilda: 172/28/110/34 (total/*Nesvorny* 001/group 9107/*Nesvorny* 002, groups 2022,2027) ***
Binary: 5 (2.9%, includes 'B', 'M', and '?')
Pole: 35 (20.3%)

Jupiter Trojans: 363/17/346 (total/Nesvorny 004,005,009/group 9202) ***
Binary: 5 (1.3%)
Pole: 26 (7.2%)

*** Total based on orbital parameters for group in Table 3)

6.1.2 SUMMARY TABLE: U >= 2- ONLY; MIN/MAX VALUES

Shortest Period: 0.003298 h (11.87 s); 2017 QG18
Longest Period: 1880 h (78.33 days); (162058) 1997 AE12
Smallest Diameter: 0.003 km; 2006 RH120, 2010 WA, 2015 TC25
Largest Diameter: 2454 km; (136199) Eris

Based on AmpMax value
Largest Amplitude: 2.80 mag; (24878) 1996 HP25
Average Amp: 0.43. mag

Total: 27,941

Amp 0.01-0.10:	850	(414 Survey, 48.7%)
Amp 0.11-0.20:	4,635	(2,998 Survey, 64.7%)
Amp 0.21-0.30:	5,443	(3,920 Survey, 72.0%)
Amp 0.31-0.40:	4,294	(3,026 Survey, 70.5%)
Amp 0.41-0.50:	3,480	(2,621 Survey, 75.3%)
Amp 0.51-0.75:	6,068	(4,747 Survey, 78.2%)
Amp 0.76-1.00:	2,411	(1,726 Survey, 71.6%)
Amp 1.01-1.50:	680	(306 Survey, 45.0%)
Amp > 1.50:	80	(22 Survey, 27.5%)

6.2.0 DETAILS TABLE - OVERVIEW

The numbers for the tumbler and binary subsets are going to be higher than reflected in the Summary table totals. This just indicates that not every suspected binary or tumbler was "good enough" to make it to the summary line.

All numbers in each subset include multiple entries for a given asteroid.

Total Records:	780,428	(includes those w/o any LC data)
With Period:	55,398	(includes those w/o U rating)
U ≥ 1–:	47,173	(Total: 85.2%. Survey: 29,784, 63.1%)
U ≥ 2–:	46,528	(Total: 84.0%. Survey: 28,382, 61.0%)

Pole: 3,944 / 3,609 / 3,058
The first number is the records with a spin axis solution. The second number is those with a period The third number is those with a period and U >= 2-

Tumblers: 706 / 510 / 498
The first number is the records that include 'T' in the notes field. The second number is those with a period (precession and/or rotation). The third number is those with a period and U >= 2–.

Binaries:

Total:	1,036	(includes 'B', 'M', and '?')
Confirmed:	744	(includes 'B', 'M')

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