ASTEROID LIGHTCURVE DATA BASE (LCDB)

Revised 2019 September 8

SPECIAL NOTICES

See Section 5 “SPARSE DATA AND WIDE-FIELD SURVEYS”

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 a 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.

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).

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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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2.0.0 DATA FILES

The LCDB release consists of 10 primary files (tables) and two version s of the pds_readme (this file; TXT and PDF), 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

pds_readme.txt pds_readme.pdf	This file of introductory information.
lc_ambiguous	Lists asteroids with ambiguous periods.
lc_binary	Lists suspected/confirmed binary/multiple asteroids
lc_colorindex	Lists color indexes of asteroids (B-V, V-R, V-I, g-r, r-i, B-R).
lc_details	Lists basic summary table information and the detailed information from individual references. There are one or more lines per asteroid.
lc_diameters	Lists summary H, p_V, D values and the same values plus errors from detail records that reported a diameter.
lc_notesex	Lists extended notes associated with summary and/or details records.
lc_npa	Lists suspected/confirmed asteroids in non-principal axis rotation (NPAR, or "tumbling").
lc_references	Lists all publications referenced in the LCDB.
lc_spinaxis	Lists asteroids with reported spin axis (poles) and/or shape models.
lc_summary	Lists 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 complete and thorough 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.

A good summary page with links to those journal references is 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, 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 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

$$\begin{aligned} DeltaP &= [0.05 / 360.0 / 24.0] * (8 ^ 2) \\ &= 0.00037 \text{ hr.} \end{aligned}$$

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.

3.1.2 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)).

(See Pravec and Harris, 2007).

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.

Taxonomic Class, orbital class, and albedo

These three values can have a complex relationship when the class and albedo are not directly obtained.

When spectroscopic or other data are available that can determine the taxonomic class exactly but no direct albedo data are available, the albedo can be assumed. This albedo can, in turn, be used to find the estimated diameter and/or H if those quantities are not directly known.

Flags in the lc_summary table indicate the source of these fields, including if they are assumed based on a combination of available data. The table below shows the assumed values used barring any direct data.

The family/group is based on orbital parameters. These are mostly for informational purposes only since the definition for some groups or families is "fuzzy" at best.

Note the distinction between a family and group. A family is a set of asteroids with a common parent body. A group is a set of asteroids with common orbital characteristics. Members of a family will almost always be in the same group, but members of a group may not necessarily be of the same family.

Here, again, progress has been dramatic since the start of the LCDB, with numerous new families and those within larger families have been identified. The list below, therefore, is only a basic one, listing the more significant families and groups.

Group/Family	Orbit parameters	Class	p_V	NOTES
Baptistina	Bottke el al	C	0.057	
Centaur	5.5 < a <= 30	C	0.057	
Centaur Comet	Centaur w/comet behavior	C	0.057	9
Comet-like orbit	Q > 5.0	C	0.057	4
Comet	exhibits coma and/or tail	C	0.057	
Eos	*a:* 2.99-3.03, *e:* 0.01-0.13, *i:* 8-12	S	0.14	
Erigone	*a:* 2.32-2.40, *e:* 0.15-0.22, *i:* 4-6	C	0.057	
Eunomia	*a*: 2.53-2.72, *e*: 0.08-0.22, *i*: 11-16	S	0.21	
Flora	*a*: 2.15-2.35, *e*: 0.03-0.23, *i*: 1.5-8	S	0.24	
Hungari	*a*: 1.78-2.0, *e*: 0.18, *i*: 16-34	ES	0.3	1
Karin	Nesvorny, private communications	S	0.26	
Koronis	*a*: 2.83-2.91, *e*: < 0.11, *i*: ≤ 3.5	S	0.24	
Main belt				
-inner	*a*: < 2.6	S	0.20	5
- inner comet	*a*: < 2.6	C	0.057	9
- middle	*a*: 2.6-2.7	SC	0.10	
- middle comet	*a*: 2.6-2.7	SC	0.10	9
- outer	*a:* 2.7-5.0	C	0.057	
- outer comet	*a*: 2.7-5.0	C	0.057	9
Mars crosser	*a*: 1.3, *q*: < 1.668, *Q* < 5.0	S	0.20	5
NEA	*q*: < 1.3	S	0.20	5
NEA (comet)	*q*: < 1.3	C	0.057	9
Nysa	*a*: 2.4-2.5, *e*: 0.12-0.21, *i*: 1.3-4.3	S	0.20	6
Phocaea	*a*: 2.25-2.5, *e*: ≥ 0.1, *i*: 18-32	S	0.23	
Planet Satellite				7
Themis	*a*: 3.08-3.24, *e*: 0.09-0.25, *i*: ≤ 3	S	0.08	
TNO/KBO	*a:* > 30	C	0.1	
Trojan				
- Jupiter	*a*: 5.05-5.4	C	0.057	
- Mars	similar to Mars	S	0.20	5
- Neptune	similar to Neptune	C	0.057	
- Saturn	similar to Saturn	C	0.057	2
- Uranus	similar to Uranus	C	0.057	2
Vestoid	*a:* 2.26-2.48, *e*: 0.03-0.16, *i:* 5-8.3	S	0.20	3

NOTES

1 An albedo of 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 None known and not likely due to perturbations by giant planets, interior and/or exterior.

3 Higher albedo (p_V = 0.4) assigned only if determined to be in V class (SMASS, etc.). Otherwise, class is 'S' and p_V = 0.20 on the presumption that the object shares orbital characteristics but not parent body.

4 Barring any other classification that meets $Q > 5$, the orbit is classified as "comet-like."

5 The default $p_V = 0.20 \pm 0.07$ for S-type objects was derived from the geometric mean of all S-type objects in the LCDB with known albedos.

6 The Nysa orbital space is polluted by a large portion of objects that are not true members of the Nysa-Hertha family and, even then, the true members are heterogeneous in nature. For this reason, we elected to treat the Nysa space the same as other unassociated inner main belt objects by using a default of S class and p_V = 0.20.

7 The planet satellite group includes small and distant natural satellites of the major planets, e.g., Himalia Jupiter VI. They are included since a number of these smaller bodies resemble asteroids in size and rotational properties.

9 Several orbital groups have been given a "comet" subclass. This is for objects within the given orbital class that have shown cometary activity, e.g., so-called "main belt comets." The Comet class is reserved for "true" comets, e.g., P/Encke and the Comet-like orbit class is still reserved for objects that have very elongated orbits but have shown no signs of cometary activity. These "comet" subclasses are given default taxonomic class of 'C' and albedo of p_V = 0.057.

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-r´ 0.23

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.

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, when available, not only the reported value but the reported error. Also included is 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 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 actually 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.

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 avalue 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 includes 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 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
Name	A30	9-38	MPC-assigned name, or designation if not named
Desig	A20	40-59	MPC primary designation, if assigned
Family	A5	61-65	The orbital group or collisional family
CSource	A1	67	Flag indicating source for taxonomic classification
Class	A5	69-73	The taxonomic class
DiamSource	A1	75	Flag indicating the source for the diameter
DiamFlag	A1	77	Flag (e.g., < or >) that qualifies the diameter
Diam	F8.3	78-85	Adopted Diameter (km)
HSource	A1	87	Flag indicating the source of the H value
H	F6.3	89-94	Adopted absolute magnitude H
HBand	A2	96-97	The photometric band of H
GSource	A1	99	Flag indicating the source of the G value
G	F6.3	101-106	Adopted phase slope parameter (G or G12; see notes)
AlbSource	A1	108	Flag indicating the source of the albedo value
AlbFlag	A1	110	Flag (e.g., < or >) qualifying the albedo value
Albedo	F6.4	112-117	Adopted Albedo (same band as H)
PFlag	A1	119	Period qualifier
Period	F13.8	121-133	Rotation period, in hours; usually synodic
PDescrip	A15	135-149	Description of period if PFlag = 'D'; e.g., "long"
AmpFlag	A1	151	Amplitude flag, e.g., > or <
AmpMin	F4.2	153-156	Minimum reported amplitude
AmpMax	F4.2	158-161	Maximum reported amplitude
U	A2	163-164	Lightcurve Quality
Notes	A5	166-170	Qualifying flags for record
Pole	A1	172	Y/N Y = Pole position reported in spin axis table
IsBinary	A1	174	? = Suspected; B = Binary; M = Multiple; blank if none
WideField	A1	176	Y/N Y = Results based on wide-field survey
SparseData	A1	178	Y/N Y = Results based on sparse data survey
NotesEx	A1	180	Y/N Y = Entry in lc_notesex table

Private	A1	182	Y/N Y = Private record. The results have been supplied for the LCDB authors' use only; the only entries will be the number/name/desig and U code, if there is one.

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.

4.1.4 LC_DETAILS COLUMN MAP

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
ShortRef	A30	81-110	Short Reference from lc_references table
WorkedAs	A20	112-131	The name or designation at the time of the observations
DateObs	A10	133-142	Mid-date (yyyy-mm-dd, 0h UT) of mid-observations
PABL	F5.1	144-148	Phase angle bisector longitude at DateObs
PABB	F5.1	150-154	Phase angle bisector latitude at DateObs
Phase	F5.1	156-160	Solar phase angle at DateObs (always positive)
Family	A5	162-166	Orbital group/collisional family, if reported
Class	A5	168-172	Taxonomic class, if reported
DiamMeth	A1	174	Method used to find reported diameter, if any
Diam	F8.3	176-183	Diameter (km), if reported
DiamErr	F8.3	185-192	Error in Diam (km), if reported
HMeth	A1	194	Method used to find H, if reported
H	F6.3	196-201	Absolute magnitude (H), if reported
Herr	F6.3	203-208	Error in H, if reported
HBand	A2	210-211	Color band for H (see notes)
GSource	A1	213	Method used to find reported G, if any
G	F6.3	215-220	Phase slope parameter (G or G12), if reported
GErr	F6.3	222-227	Error in G, if reported
AlbSource	A1	229	Method to find albedo, if reported
AlbFlag	A1	231	Flag qualifying albedo value, e.g., < or >
Albedo	F6.4	233-238	Albedo, if reported (same band as H, if reported)
AlbErr	F6.4	240-245	Error in albedo, if reported
PFlag	A1	247	Period qualifier
Period	F13.8	249-261	Rotation period, hours; usually synodic

PerErr	F10.8	263-272	Error in period, hours
PDescrip	A15	274-288	Description of period if PFlag = 'D'; e.g., "long"
AmpFlag	A1	290	Amplitude qualifier, e.g., > or <
AmpMin	F4.2	292-295	Minimum amplitude, if reported
AmpMax	F4.2	296-299	Maximum amplitude, if reported
AmpErr	F4.2	301-304	Error in AmpMax, if reported
U	A2	306-307	Lightcurve Quality
Notes	A5	309-313	Qualifying flags for record
Pole	A1	315	Y/N Y = Pole position reported in spin axis table
IsBinary	A1	317	? = Suspected; B = Binary; M = Multiple; blank if none
WideField	A1	319	Y/N Y = Results based on wide-field survey
SparseData	A1	321	Y/N Y = Results based on sparse data survey
NotesEx	A1	323	Y/N Y = Entry in lc_notesex table
Private	A1	325	Y/N Y = Private record. The results have been supplied for the LCDB authors' use only; the only entry will be the number/name/desig and U code, if there is one.

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.

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)

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., 2011)

H Color Band

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

Blank	Johnson V
B	Johnson B
V	Johnson V
R	Cousins R
I	Cousins I
SU	Sloan u´
SG	Sloan g´
SR	Sloan r´
SI	Sloan i´
SZ	Sloan z´

G Method/Source Flags

A	From Lowell ASTORB table
D	Default for taxonomic class (see Warner et al., 2009)
G	Based on H-G12 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., 2011)

Diameter Qualifier Flags

<	Diameter is a maximum
>	Diameter is a minimum

Diameter Method/Source Flags

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., 2011)

Albedo Method/Source Flags

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., 2011)

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.

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)
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 includes 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 includes 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_notesex table indicates otherwise, the bands are on the Johnson-Cousins BVRI and Sloan griz 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

4.5.0 LC_DIAMETERS

This table is provided for those wanting to quickly 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
Name	A30	9-38	MPC-assigned name, or designation if not named
SumPer	F13.8	40-52	Rotation period from summary table, hours
SHBand	A2	54-55	Photometric band for H from the summary record
SumH	F6.3	57-62	Absolute magnitude (H) from summary record
SumG	F6.3	64-69	Phase slope parameter (G) from summary record
SumPv	F6.4	71-76	Albedo from summary record
SumDiam	F8.3	78-85	Diameter (km) from the summary record
SumNotes	A5	87-91	Qualifying flags for the summary record (See Notes section after lc_details)
ShortRef	A30	93-122	Short reference from lc_references table
DateObs	A10	124-133	Mid-date (yyyy-mm-dd, 0h UT) of observations
DetPer	F13.8	135-147	Rotation period from details record, hours
DetPerErr	F13.8	149-161	Error in rotation period
DetHSource	A1	163	Flag indicate method used to find reported diameter
DHBand	A2	165-166	Photometric band of H
DetH	F6.3	168-173	Absolute magnitude (H) from details record
DetHErr	F6.3	175-180	Error in H
DetGSource	A1	182	Flag indicating method use to find reported G
DetG	F6.3	184-189	Phase slope parameter (G or G12) from details record
GetGErr	F6.3	191-196	Error in G
DetPv	F6.4	198-203	Albedo from details record, same band as H
DetPvErr	F6.4	205-210	Error in albedo
DetDiam	F8.3	212-219	Diameter (km) from details record
DetDiamErr	F8.3	221-228	Error in diameter
DetNotes	A5	230-234	Qualifying flags for the details record (See Notes section after lc_details)

4.6.0 LC_NOTESEX

The lc_notesex 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 NotesEx 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.

4.6.1 LC_NOTESEX 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 "SumNotesEx" would use the <no data> value. For details note only record, the "Number" and "Name" fields would have values but the "SumNotesEx" 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
SumNotesEx	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
DetNotesEx	A1024	92-1115	Extended note for detail record

4.7.0 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.

4.7.1 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.

4.7.2 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)

4.8.0 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.

4.8.1 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.

4.9.0 LC_SPINAXIS (POLE SOLUTIONS)

This table includes 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.

4.9.1 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.

4.9.2 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.

4.9.3 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 4.8.1)

5.0.0 WIDE-FIELD SURVEYS AND SPARSE DATA SETS

5.1.0 WIDE-FIELD SURVEYS

Since about 2012, several papers have been published that made use of the Palomar Transit Factory survey. The combined papers have added more than 10,000 new asteroids to the LCDB.

The first two papers, Polishook et al. (2012) and Chang et al. (2014), produced a manageable number of lightcurves, meaning that each one was reviewed by the LCDB authors and a U code assigned. More recent papers, e.g., Waszczak et al. (2015) and Chang et al. (2015), produced thousands of "reliable" lightcurves. For these two papers, and those likely to follow, it is not possible to review each lightcurve.

As a result, the LCDB authors adopted the policy of assigning U = 2 to any lightcurve from the two later papers above where the original authors claimed to have found a reliable period. The Waszczak paper found a number of periods that were not considered reliable. These 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.

Over time, at least some individual entries will be reviewed and, if necessary, the summary line will be updated.

N.B. The Waszczak et al. (2015) paper reported observations on more than 50,000 asteroids but found less than 10,000 "reliable" periods, or about a 16% success rate. The Chang 2015 paper had about a 27% success rate. As a result, statistical studies should use the wide-field data with some caution since they have likely introduced substantial biases, e.g., 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.

For a detailed look at these issues, the reader is referred to 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.

The LCDB authors anticipate having to handle the results based on similar large surveys in the future. These will be handled on a case-by-case basis.

5.2.0 SPARSE DATA SETS

Sparse data sets differ from their wide-field counterparts in that they 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.

These sparse data sets can be used exclusively in shape modeling and spin axis studies (e.g., Hanus et al., 2016). If a period and/or spin axis is generated by the use of sparse data _only_, the SPARSEDATA field will be set to TRUE in the details and/or summary record.

Depending on the number of data points involved, the result may be given a U rating of 2 even though the NOTES flag will include 'N' for no published lightcurve. If the only period result, the value is included on the summary line, which will also have the SPARSEDATA field set along with the U rating field.

In those cases where sparse data are combined with dense lightcurves, the sparse data field will NOT be set but, as above, the result may be given a U rating and 'N' in the in NOTES field and, if the only period result, migrated to the summary line.

6.0.0 NUMBERS OF INTEREST

The numbers presented here are as of 2019 August 14.

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:	325184
Non-Orphan:	24611
WideField:	17887 (orphan, detail source is from a WF survey)
WideField:	15985 (non-orphan)
SparseData:	0 (detail source is from a SD survey)
SparseData:	0 (non-orphan)
U >= 1-:	21294* (non-orphan)
U >= 2-:	19564 (non-orphan)

* This is the number of entries in the lc_summary table and so 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:	2701 (could be just "retrograde vs. prograde"
Tumblers:	504
Binaries:	504 (includes suspected)
Binaries:	304 ('B' or 'M', i.e., considered confirmed)

6.1.0 SUMMARY TABLE: U >= 2- ONLY

NEA: 1534

Binary: 95 (6.2%, includes 'B', 'M', and '?')

Pole: 65 (4.2%)

Hungaria: 463

Binary: 50 (10.8%, includes 'B', 'M', and '?')

Pole: 34 (7.3%)

Hilda: 159

Binary: 2 (1.3%, includes 'B', 'M', and '?')

Pole: 21 (13.2%)

Jupiter Trojans: 346

Binary: 4 (1.1%)

Pole: 18 (5.2%)

6.1.1 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, 2915 TC25

Largest Diameter: 2700 km; (136199) Eris

Based on AmpMax value

Largest Amplitude: 2.79 mag; 2014 KH39

Average Amp: 0.47 mag

Total: 19655

Set	All	
Amp 0.01-0.10:	526	(94 Wide/Sparse, 18% 2.7%)
Amp 0.11-0.20:	2554	(1028 Wide/Sparse, 40% 5.2%)
Amp 0.21-0.30:	2937	(1541 Wide/Sparse, 60% 7.8%)
Amp 0.31-0.40:	2727	(1559 Wide/Sparse, 57% 13.9%)
Amp 0.41-0.50:	2366	(1598 Wide/Sparse, 68% 12.0%)
Amp 0.51-0.75:	4698	(3510 Wide/Sparse, 75% 23.9%)
Amp 0.76-1.00:	2082	(1443 Wide/Sparse, 69% 10.6%)
Amp 1.01-1.50:	562	(240 Wide/Sparse, 43% 2.9%)
Amp > 1.50:	57	(5 Wide/Sparse, 9% 0.2%)

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:	619159	(includes those w/o any LC data)
With Period:	38919	(includes those w/o U rating)
U >= 1-:	34982	(89.9% Wide/Sparse: 16911, 43.5%)
U >= 2-:	32104	(82.5% Wide/Sparse: 15554, 40.0%)

Pole: 3808/3495/3021
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: 639/638/432 (307/174)
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:	844	(includes 'B', 'M', and '?')
Confirmed:	603	(includes 'B', 'M')

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