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VOIDS AND QUESTION MARKS IN THE PRESENT-DAY DATA CONCERNING THE ROTATION PERIOD OF THE FIRST 1000 NUMBERED ASTEROIDS

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Currently, there are only 19 three-digit numbered asteroids – none of them within the first 500 – for which their rotation period is unknown. Chances are that all of the first 1000 asteroids will have a known period in just a few years. However, not all of the 981 present-day published rotation period data for asteroids numbered below 1000 are secure. Ongoing investigations to verify, refine, or revise existing periods remains an important endeavor, especially for the 17 asteroids for which the period is currently uncertain.

The more complete the sampling of asteroid rotation periods, the better astronomers can develop theories concerning the origin and dynamics of the minor planet system. No matter how large the database on asteroid rotation periods, which has being steadily growing at an accelerated pace, mostly due to the contribution from amateurs. A lot of hard work still awaits.

In the last issue of the *Minor Planet Bulletin*, Alan W. Harris (2015) properly put into perspective how far the field of asteroid photometry has come in the past forty years, i.e., since the first asteroid lightcurve observations were published in 1974 in the *MPB*. He remarked that, while prior to that year, there were known rotation periods for only 64 asteroids – some of them even wrong – "today we have fairly reliable periods for more than 5000 asteroids." Taking into account that there are more than 650,000 asteroids with well-defined orbits, this means that we currently know the rotation period for less than 0.8% of that number.

This paper focuses on what we now know about the rotation period of the first 1000 numbered asteroids – as these are generally speaking the brightest ones and, therefore, generally the easiest asteroids to observe. At the time of this study (early 2015), there remain 19 asteroids for which no rotation period has been found in the literature (Table I).

Just one year ago, of all the 3-digit numbered asteroids there were 31 with no reported rotation period (Alvarez and Pilcher, 2014). Since then, a period has been reported for 12 (~ 40%) of those, including the only four asteroids numbered below 500 that remained without a reported rotation period. Considering how rapidly such data voids have been filled, it is almost certain that by the end of the decade a reliable period will be found for all of the first 1000 numbered asteroids. However, the goal of determining the period for all 3-digit numbered asteroids will not be fully accomplished just by finding periods for the 19 remaining objects. Any measured rotation period value should also be – to put in Alan W. Harris' own words – "fairly reliable." Currently, 17 of the first 1000 numbered asteroids have only preliminary periods, i.e., not "fairly reliable."

The asteroid lightcurve database (LCDB; Warner *et al.*, 2009) assigns a U code, which provides an assessment of the quality of the period solution. A quality code U = 3 means that the corresponding rotation period is basically correct; U = 2 means that the found rotation period is likely correct, although it may be wrong by 30% or it is ambiguous (e.g., the half or double period may be correct); U = 1 means that the established rotation period may be completely wrong. According to the latest public release of the LCDB (2014 December 13), of the 981 asteroids numbered below 1000 that have a published rotation period, there are 17 that have been assigned U = 1 (Table II), 146 have U = 2 (Table III), and the remaining 818 asteroids are rated U = 3.

The 17 asteroids that been assigned U = 1 should be given higher priority when selecting new targets to work. Their respective period values need to be verified or refined. Figure 1 shows how their corresponding rotation periods are distributed. The median value is 18 hours, so that there are 8 asteroids with relatively short periods (from 4 up to 15 hours) and another 8 with relatively long periods (from 24 up to 150 hours). Of the second group, it will be particularly harder to resolve those asteroids that appear to have period values commensurable to the Earth's rotation (318 Magdalena, 467 Laura, 837 Schwarzschilda, and 957 Camelia). In order to obtain full lightcurve coverage, it will likely require the collaboration of several observers who are widely distributed in longitude. Such endeavors have become a growing practice.

The median period of the 146 asteroids assigned U = 2 is 16.5 hours, or similar to the median value corresponding to the U = 1 group. There are 73 3-digit numbered asteroids with rotation periods shorter than 16.5 hours but that are not yet completely reliable. Given the relatively short periods, a single observer's time and resources might be best invested by first focusing on the periods that may be solidified from a single location.

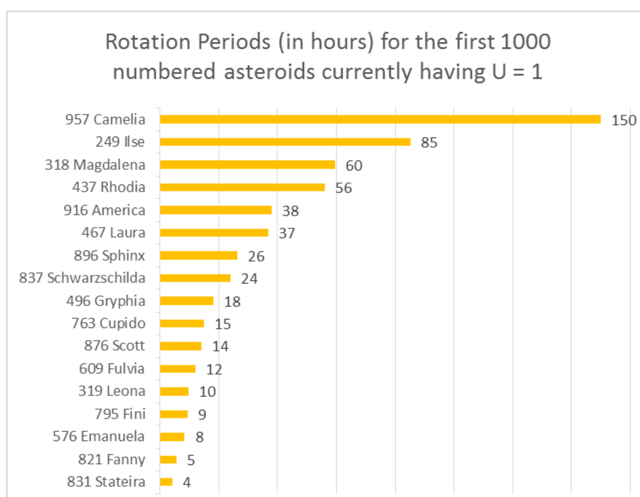

Figure 1. The 17 3-digit asteroids which periods have been rated U = 1. The periods are in hours, rounded to integer numbers.

Number	Name	Number	Name
515	Athalia	843	Nicolaia
637	Chrysothemis	848	Inna
646	Kastalia	871	Amneris
703	Noemi	910	Anneliese
717	Wisibada	930	Westphalia
722	Frieda	941	Murray
767	Bondia	961	Gunnie
820	Adriana	991	McDonalda
835	Olivia	993	Moultona
842	Kerstin		

Table I. The 19 asteroids numbered below 1000 for which no rotation parameters were known at the beginning of 2015.

Number	Name	U	Period (h)
249	Ilse	1	85.24
318	Magdalena	1	59.5
319	Leona	1	9.6
437	Rhodia	1	56
467	Laura	1	36.8
496	Gryphia	1	18.0
576	Emanuela	1-	8.192
609	Fulvia	1+	12
763	Cupido	1	14.88
795	Fini	1+	9.292
821	Fanny	1	5.44
831	Stateira	1	4
837	Schwarzschilda	1	24
876	Scott	1	14
896	Sphinx	1	26.270
916	America	1	38
957	Camelia	1+	150

Table II. The 17 asteroids numbered below 1000 for which the quality of the found rotation period appeared to be U = 1 at the beginning of 2015. The rotation periods are expressed in hours and each shows as many significant digits as are currently known.

Number	Name	U	Period (h)
227	Philosophia	2	52.98
248	Lameia	2	12.00
254	Augusta	2	6.0
269	Justitia	2	16.545
279	Thule	2+	15.962
299	Thora	2+	274
305	Gordonia	2	16.2
314	Rosalia	2	20.43
329	Svea	2+	22.77
331	Etheridgea	2	13.092
341	California	2+	317
346	Hermentaria	2	28.43
357	Ninina	2+	36.0105
375	Ursula	2	16.83
384	Burdigala	2-	21.1
392	Wilhelmina	2	17.96
393	Lampetia	2-	38.7
395	Delia	2	19.71
396	Aeolia	2-	22.2
398	Admete	2	11.208
407	Arachne	2	22.62
421	Zahringia	2	6.42
422	Berolina	2	12.79
425	Cornelia	2	17.56
426	Hippo	2	34.3
431	Nephele	2	18.821
439	Ohio	2	19.2
445	Edna	2	19.97
449	Hamburga	2+	18.263
450	Brigitta	2	10.75
455	Bruchsalia	2+	11.838
458	Hercynia	2	22.3
460	Scania	2	9.56
464	Megaira	2	12.726
470	Kilia	2	290

Number	Name	U	Period (h)
477	Italia	2	19.42
478	Tergeste	2+	16.104
481	Emita	2	14.35
491	Carina	2+	15.153
494	Virtus	2+	5.57
503	Evelyn	2	38.7
507	Laodica	2	6.737
521	Brixia	2-	9.78
527	Euryanthe	2-	26.06
529	Preziosa	2	27
537	Pauly	2+	14.15
548	Kressida	2	11.9404
551	Ortrud	2	13.05
555	Norma	2+	19.55
569	Misa	2	13.52
570	Kythera	2	8.120
581	Tauntonia	2	16.54
583	Klotilde	2	9.2116
589	Croatia	2+	24.821
597	Bandusia	2	15.340
605	Juvisia	2	15.93
613	Ginevra	2	13.024
618	Elfriede	2	14.801
619	Triberga	2	29.412
622	Esther	2	47.5
625	Xenia	2	21.101
630	Euphemia	2	350
645	Agrippina	2	32.6
662	Newtonia	2	16.46
664	Judith	2+	10.9829
666	Desdemona	2+	14.607
673	Edda	2	14.92
676	Melitta	2	7.87
684	Hildburg	2	15.89
691	Lehigh	2+	12.891
705	Erminia	2	53.96
707	Steina	2+	414
716	Berkeley	2+	15.55
730	Athanasia	2+	5.7345
738	Alagasta	2	17.83
739	Mandeville	2	11.931
741	Botolphia	2-	23.93
746	Marlu	2	7.787
748	Simeisa	2	11.919
761	Brendelia	2+	57.96
764	Gedania	2	24.9751
768	Struveana	2+	8.76
774	Armor	2	25.107
777	Gutemberga	2	12.88
783	Nora	2-	34.4
784	Pickeringia	2	13.17
786	Bredichina	2+	18.61
788	Hohensteina	2	29.94
791	Ani	2	16.72
807	Ceraskia	2	7.4
814	Tauris	2	35.8
819	Barnardiana	2+	66.70
823	Sisigambis	2	146
828	Lindemannia	2	20.52
830	Petropolitana	2	39.0
838	Seraphina	2	15.67
845	Naema	2	20.892
846	Lipperta	2	1641
850	Altona	2+	11.197
856	Backlunda	2	12.08
857	Glasenappia	2	8.23
858	El Djezair	2	22.31
859	Bouzareah	2-	23.2
862	Franzia	2	7.52
863	Benkoela	2+	7.03
866	Fatme	2	20.03
868	Lova	2	41.3
873	Mechthild	2	10.6

Number	Name	U	Period (h)
874	Rotraut	2	14.586
879	Ricarda	2	82.9
882	Swetlana	2-	20
887	Alinda	2	73.97
891	Gunhild	2	7.93
892	Seeligeria	2	41.40
895	Helio	2	9.3959
897	Lysistrata	2	11.26
900	Rosalinde	2	16.5
902	Probitas	2+	10.117
903	Nealley	2	21.60
904	Rockefellia	2	5.82
917	Lyka	2	7.92
920	Rogeria	2-	8.09
923	Herluga	2	19.746
926	Imhilde	2	26.8
927	Ratisbona	2	12.994
931	Whittemora	2	19.20
932	Hooveria	2+	39.1
936	Kunigunde	2	8.80
938	Chlosinde	2	19.204
946	Poesia	2+	108.5
949	Hel	2	10.862
952	Caia	2	7.51
953	Painleva	2-	7.389
958	Asplinda	2	25.3
960	Birgit	2+	8.85
965	Angelica	2	17.772
969	Leocadia	2	6.87
973	Aralia	2+	7.29
981	Martina	2	11.267
982	Franklina	2-	16
983	Gunila	2	8.37
988	Appella	2	120
992	Swasey	2	13.308
994	Otthild	2+	5.95
997	Priska	2	16.22
999	Zachia	2	22.77

Table III. The 146 asteroids numbered below 1000 for which the quality of the found rotation period appeared to be U = 2 at the beginning of 2015. The rotation periods are expressed in hours and each shows as many significant digits as are currently known.

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ASTEROIDAL OCCULTATION BY 82 ALKMENE AND THE INVERSION MODEL MATCH

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On 2014 September 18, the asteroid 82 Alkmene occulted HIP 99229 for observers in the western United States. Four well-spaced chords allowed matching these observations with one of the two convex shape models available for this asteroid. Results of this event can be found on the North American Asteroidal Occultation Results webpage.

The history of asteroidal occultation observations has been reviewed before (Timerson *et al*., 2009). Successful predictions (Preston, 2009) and observations have increased dramatically, especially since 1997, aided by high-accuracy star catalogs and asteroid ephemerides (Dunham *et al*., 2002). Other prediction information is available in Timerson *et al*., 2009.

The techniques and equipment needed to make these observations are outlined in the IOTA manual (Nugent, 2007). Observations are reported to a regional coordinator who gathers these observations and uses a program called *Occult4* (Herald, 2015) to produce a profile of the asteroid at the time of the event. The asteroidal occultation data are officially deposited and archived and made available to the astronomical community through the NASA Planetary Data System (Dunham *et. al.*, 2014). Additional tools such as asteroid lightcurves (Warner, 2011) and asteroid models derived from inversion techniques (Durech et al., 2010) can be combined with occultation results to yield high resolution profiles.

Names	Telescope	Imager	Time Inserter	Integration
C. Arrowsmith, W. Anderson	28 cm SCT	Mallincam	IOTA-VTI	2 frames
J. Bardecker	30 cm SCT	Mallincam	IOTA-VTI	No
T. Beard	20 cm SCT	PC165DNR	IOTA-VTI	2 frames
C. Coburn, T. Smoot, H. Hill	36 cm SCT	Mallincam	IOTA-VTI	No
H. Gimple	28 cm SCT	Mallincam	IOTA-VTI	4 frames
C. McPartlin	13 cm Refr	Stellacam II	IOTA-VTI	No
W. Morgan	20 cm SCT	PC164C	IOTA-VTI	No
K. Schindler, J. Wolf	60cm R-C	Andor DU-888	Other GPS	No

Table 1. Observers and the equipment used. SCT = Schmidt-Cassegrain, Refr = Refractor, R-C = Richey-Chrétien