

To illustrate the improvement with attention to epoch sampling I present as an example the data set of asteroid (347) Pariana, which was observed during its 2009 apparition by Caspari (2010). The author combined the new data with lightcurves from two earlier apparitions to report a sidereal period result which seems to have been selected based on a statistical approach. I will use Eqs. 3–5 to test what degree of ambiguity is present within the initial constraint on the sidereal period, based on Δt , P_{syn} , and $\sigma_{99}(P_{\text{syn}})$.

In the Pariana data set the interval Δt is about 93 months between the closest epochs not in the same apparition, which are six apparitions apart in 1991 and 1999. The synodic rotation period P_{syn} is 4.052 h, with reported errors (assumed 1-sigma) estimated separately from pre- and post-opposition lightcurve subsets. The period uncertainty for use in Eq. 3 should properly be estimated directly from a combined analysis of the original data over the entire 52-day interval observed, but for illustration purposes only I'll use the available information to approximate the uncertainty of a period derived from the combined data. The precision of the combined time interval will be limited by the greater noise in the 16-day span of post-opposition data, so I scale their reported period error $\sigma(P_{\text{syn}}) = 0.004$ h by the ratio 16/52, which simply divides the same interval error by the larger number of rotations that occur over the longer 52-day span. Then I adopt $\sigma_{99} \approx 2.5\sigma$ yielding a final estimate of 0.003 h for $\sigma_{99}(P_{\text{syn}})$.

The result is that the Pariana epochs allow about 50 alias periods within the initial constraint on the sidereal period, a significant ambiguity which suggests that the reported sidereal period solution is spurious. Caspari (2010) also reported a corresponding spin vector solution based on a nonlinear iterative inversion algorithm (Kaasalainen et al., 2001) which requires the sidereal period as an initial input value, so if the sidereal period is spurious then so is the pole solution.

The Pariana data set can be made markedly more suitable for constraining the sidereal period with additional lightcurve observations that satisfy the two precepts described earlier:

1. Observe a future apparition for a span longer than was observed in 2009. For example, if the observations during the 2009 apparition had begun at the start of the preceding lunation then the total span of available epochs would be 60% longer, and data of comparable quality recorded then would have reduced the number of alias periods by that same amount.
2. Observe lightcurves during a consecutive pair of future apparitions as close as possible in time. Pariana's orbit eccentricity 0.16 is large enough that the time intervals between consecutive apparitions vary in length by nearly a factor of two; the shortest intervals occur when one of the opposition dates is in July or August. For example, if Pariana were observed in 2012 February and 2013 July then Δt would be about 17 months, reducing by more than 80% the number of alias periods.

Making both of the above improvements to the Pariana data set reduces the expected number of alias periods for the initial sidereal period constraint to about 3, few enough to convincingly check individually.

Conclusion

Authors determining sidereal rotation periods from lightcurves need to be aware of the issue of alias periods, and use analysis methods that explicitly address identifying and resolving ambiguous solutions for rotation counts. Attention to epoch

sampling in the observing program can reduce the number of alias periods. Robust strategies are needed to reliably identify the correct period from among aliases, or to establish the degree to which the best result is ambiguous; in particular, if a statistical approach ultimately is involved then one must be mindful of its limitations in this context.

Finally, note that while significant ambiguity in the rotation count for the initial sidereal constraint considered here would suggest that the epoch data are insufficient to determine the sidereal period, an unambiguous rotation count at this initial stage does not by itself guarantee that the full data set is sufficient to unambiguously count rotations over the longer intervals of the entire data set, or that the sidereal period thus obtained is accurate enough. In the second paper I will describe a method to estimate bounds on the range(s) of sidereal periods that are consistent with an entire data set of epochs.

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A DETERMINATION OF THE ROTATIONAL PERIOD OF 8882 SAKAETAMURA

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CCD Observations of 8882 Sakaetamura were taken on nine nights between 2012 Jan 7 and 29. Analysis of the data found a synodic period of 4.874 ± 0.002 h with a lightcurve amplitude of 0.60 ± 0.1 .

8882 Sakaetamura is a main-belt asteroid that was discovered on 1994 Jan 10 by K. Endante and K. Watanabae at Kitami. Alternate designations for this asteroid are 1994 AP2 and 1987 GX (JPL, 2012). Observations were made at the Frank T. Etsorn Observatory located on the campus of the New Mexico Institute of Mining and Technology. The equipment used for observations included a 0.35-m $f/11$ Cassegrain mounted on a Paramount ME and SBIG STL-1001E CCD camera. All images were taken through a clear filter and the exposure times were 180 seconds. The images were flat-corrected and dark-subtracted and then aligned using *CCDSOFT 5* (Software Bisque). The period analysis and lightcurve generation were done using *MPO Canopus* (MPO Software).

The period analysis found a synodic period for 8882 Sakaetamura of 4.874 ± 0.002 h. This is different from the period reported by Hamanowa and Hamanowa (2005), who found 2.838 h with an amplitude of 0.66 mag. Their solution was a monomodal lightcurve which, given the amplitude, is not likely and so a period approximately double what they found would be more probable. On the other hand, the solution is almost identical to the one of 4.8742 ± 0.002 h found by Hills (2012).

Acknowledgements

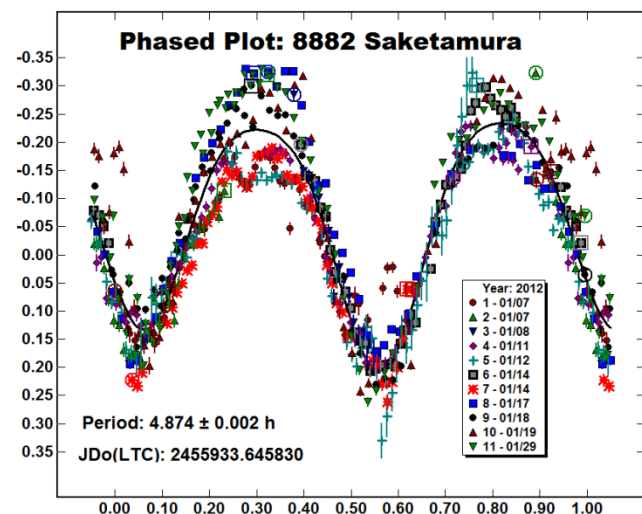
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LIGHT CURVE FOR 8345 ULMERSPATZ

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The main-belt asteroid 8345 Ulmerspatz was observed by a collaboration of four observatories on 24 nights between 2011 Nov 24 and 2012 Jan 12, covering solar phase angles between -22.58° and $+10.48^\circ$. The average synodic period for the entire observing period is estimated to be 17.1192 ± 0.0008 h with an amplitude of 0.70 ± 0.10 mag.

The main-belt asteroid 8345 Ulmerspatz was discovered on 1987 January 22 by E. W. Elst at the European Southern Observatory. The orbital period is 3.575 years and inclination 23.4° . Over the years, it has carried designations 1987 BO1, 1968 YB, and 1994 AU2 (JPL, 2012). It is named for the Ulmerspatz (sparrow) copper statuette originally on top of the roof of the cathedral of Ulm. The legend goes that a sparrow, building its nest, showed the builders of Ulm how to move a large beam through a small entrance door.

CCD observations of 8435 Ulmerspatz were obtained by a collaboration of four observatories from late 2011 to early 2012. The Etsorn Campus Observatory used a 35.6-cm $f/11$ Schmidt-Cassegrain telescope and SBIG STL-1001E CCD with 1024×1024 24-micron pixels, which gave a plate scale of 1.25 arcseconds/pixel. The exposure time for all images was 180 seconds through a clear filter. The CCD was cooled to -30°C or -35°C , depending on the night-time temperature. The images processed with dark frames and flat fields and then aligned using IDL routines developed by KlingleSmith (Visual Information Solutions, 2012). The processed images were measured with *MPO Canopus* (Warner, 2011). The Bigmuskie Observatory used a 30-cm $f/8$ Ritchey-Chretien and SBIG ST-9 with 512×512 20-micron pixels resulting in a plate scale of 1.72 arcseconds/pixel. The exposure time for all images was 240 seconds through an R

Start	Stop	Phase	Period (h)	Perr	Amp	Aerr
2011-11-24	2011-12-02	-22.6	17.1128	0.0150	0.60	0.05
2011-12-03	2011-12-08	-17.9	17.1724	0.0072	0.60	0.05
2011-12-16	2011-12-24	-9.4	17.0840	0.0060	0.65	0.05
2011-12-26	2011-12-29	-2.4	17.1508	0.0060	0.67	0.10
2011-12-31	2012-01-03	1.6	17.0316	0.0132	0.57	0.05
2012-01-05	2012-01-12	5.2	17.1300	0.0060	0.80	0.10

Table I. Observing circumstances and lightcurve analysis results for specific date ranges. The columns are: starting date and ending date (yyyy-mm-dd) of the subset of data, solar phase angle, period and period error in hours, amplitude and amplitude error in magnitude.