OCCULTATIONS BY 81 TERPSICHORE AND 694 EKARD IN 2009 AT DIFFERENT ROTATIONAL PHASE ANGLES

Brad Timerson
International Occultation Timing Association (IOTA)
623 Bell Rd., Newark, NY, USA
btimerson@rochester.rr.com

J. Durech, Faculty of Mathematics and Physics Astronomical Institute
Charles University in Prague
V Holesovickach 2
18000 Prague
Czech Republic

F. Pilcher, ALPO Minor Planets Section
4438 Organ Mesa Loop
Las Cruces, NM 88011-8403 USA

J. Albers, T. Beard, B. Berger, B. Berman, D. Breit, T. Case, D. Collier, R. Dantowitz, T. Davies, V. Desmarais, D. Dunham, J. Dunham, J. Garlitz, L. Garrett, T. George, M. Hill, Z. Hughes, G. Jacobson, M. Kozubal, Y. Liu, P. Maley, W. Morgan, P. Morris, G. Mroz, S. Pool, S. Preston, R. Shelton, S. Welch, J. Westfall, A. Whitman, P. Wiggins
IOTA

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During 2009, IOTA observers in North America reported about 250 positive observations for 94 asteroidal occultation events. For two asteroids this included observations of multiple chords on two different dates which allowed well-defined profiles to be obtained at different rotational phase angles. Occultations by 81 Terpsichore on 2009 November 19 and 2009 December 25 yielded best-fit ellipses of 134.0 x 108.9 km and 123.6 x 112.2 km, respectively. Observations of 694 Ekard on 2009 September 23 and 2009 November 8 yielded fitted ellipses of 124.9 x 88.0 km and 88.5 x 104.0 km, respectively.

Introduction

The history of asteroidal occultation observations was reviewed in a previous *Minor Planet Bulletin* article (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). 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, 2008) to produce a profile of the asteroid at the time of the event. These asteroidal occultation data are officially deposited and archived, and made available to the astronomical community through the NASA Planetary Data System (Dunham, et. al., 2008). Additional tools such as asteroidal lightcurves (Pilcher) and asteroidal models derived from inversion techniques (Durech) can be combined with occultation results to yield high resolution profiles. The asteroid lightcurve inversion method is described by Kaasalainen and Torppa (2001) and Kaasalainen et al. (2001). It enables one to derive asteroid shape, spin axis direction, and rotation period from its lightcurves observed over several apparitions. The shape is usually modeled as a convex polyhedron. When the shape model and its spin state are known, its orientation with respect to an observer (sky plane projection) can be easily computed. Such a predicted silhouette can then be compared with the occultation chords and scaled to give the best fit. Finally, planning software called *OccultWatcher* allows observers to space themselves across the predicted path of the occultation to gather as many unique chords as conditions allow (Pavlov, 2008).

Occultation Results

81 Terpsichore. North American observers captured Terpsichore occulting stars on two occasions late in 2009. During these events, multiple chords were obtained allowing for the creation of a well-defined profile at different rotational phase angles. On 2009 November 19 at 10:31 UT asteroid 81 Terpsichore occulted the V magnitude 9.0 star TYC 2342-00278-1 (SAO 56567) in Perseus over a long path which included VT and NH. Maximum duration was predicted to be 13.8 seconds. For this event, 3 observers at 6 sites recorded 5 chords across the profile of the asteroid. Three sites used video to record the event while three stations used visual techniques. One station reported no occultation. D. Dunham set up 4 stations, all of which recorded positive events. The resulting chords and least squares ellipse from *Occult4* are shown in Figure 1. These chords produce a smooth ellipse with dimensions of 134.0 ± 4.0 x 108.9 ± 0.7 km. The maximum occultation duration of 12.86 seconds occurred at station 6 and is 7% shorter than predicted, likely because of the orientation of the asteroid at the time of the occultation. The observed path was quite close to the prediction.

About 106 rotational periods later, on 2009 December 25 at 5:00 UT, 81 Terpsichore occulted the V magnitude 8.5 star TYC 1795-00251-1 (SAO 75766) in Aries over a path that included areas from central Canada, through MT and to the coast of central CA. Maximum duration was predicted to be 43.7 seconds. Twelve observers at 12 sites recorded 10 positive occultations and 2 misses. Nine stations used video recording techniques while 3 used visual. The maximum observed duration was 41.36 seconds at station 8, 5% shorter than predicted. The observed path was

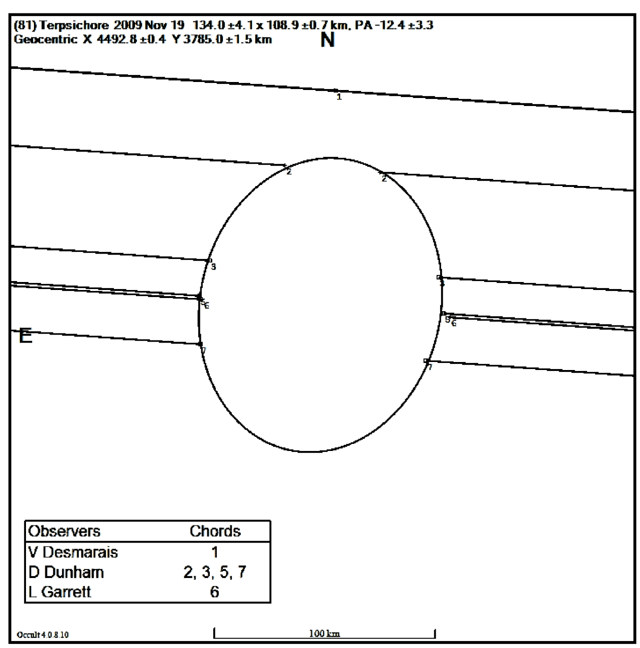

Figure 1. Observed occultation outline for 81 Terpsichore on 2009 November 19 UT with least squares ellipse.

quite close to the prediction. The resulting chords with least squares ellipse from *Occult4* are shown in Figure 2. These chords produced an ellipse with dimensions of 123.6 ± 0.3 x 112.2 ± 0.6 km.

A lightcurve from recent observations of 81 Terpsichore was provided by Frederick Pilcher (Pilcher, 2009), seen here in Figure 3. On the diagram, Pilcher determined the locations along the lightcurve corresponding to the times of the two well-observed occultations. From the profiles, the fitted ellipse areas are approximately 45,844 km^2 for the November event and 43,567 km^2 for the December event. This gives an area ratio of 0.95. However, in looking at the lightcurve, the brightness ratio is 1.05. This inconsistency might be attributed to a lack of sufficient chords for the November event such that important profile information is missed, or the somewhat noisy lightcurve data. This only serves to emphasize the need for better coverage over the entire profile of an asteroid during occultations and, with more data, improved lightcurves and lightcurve inversion models.

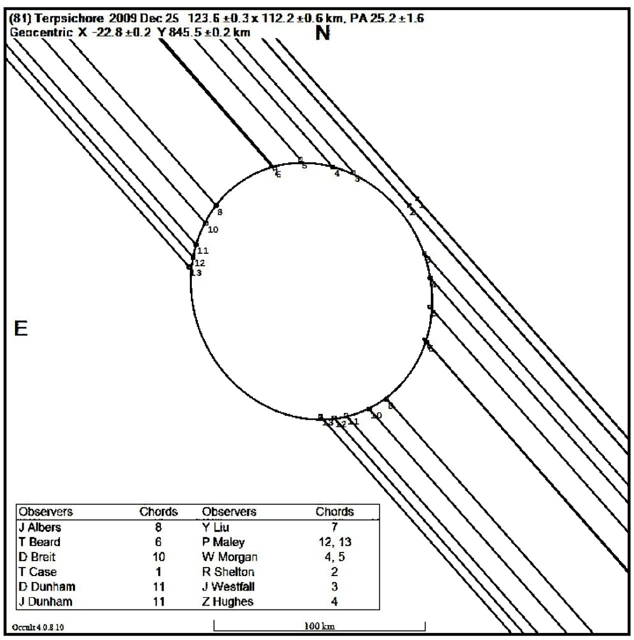

Figure 2. Observed occultation outline for 81 Terpsichore on 2009 December 25 UT, with least squares ellipse.

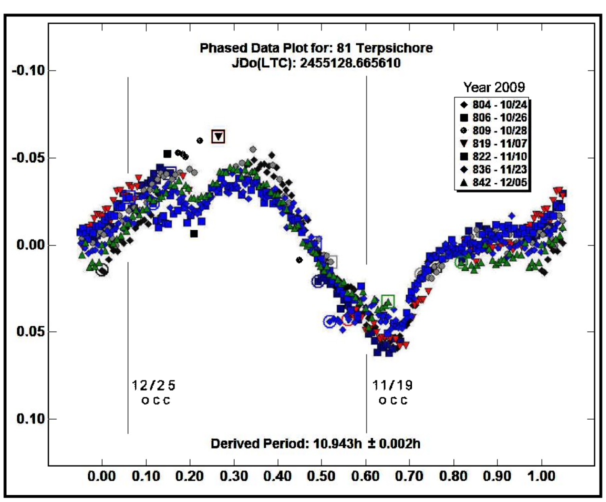

Figure 3. Pilcher lightcurve showing location of two events Involving 81 Terpsichore.

694 Ekard. North American observers captured Ekard occulting stars during four separate events in 2009. On two of those occasions, multiple chords were obtained allowing for the creation of a well-defined profile at different rotational phase angles. On 2009 September 23, from 4:35 UT to 4:42 UT, asteroid 694 Ekard occulted the V mag. 10.3 star TYC 0506-00521-1 in Aquila along a path which included the Pacific NW to southern TX. The maximum predicted duration for this event was 11.2 seconds. Eight observers provided 4 well-spaced chords. Four observers reported misses. For the positive chords, video recording was employed at 3 stations and one used drift scan. Detailed results with maps showing the locations of all observers are posted on the IOTA *Asteroid Occultation Results for North America* webpage (Timerson, 2009). The predicted orientation of Ekard provided by

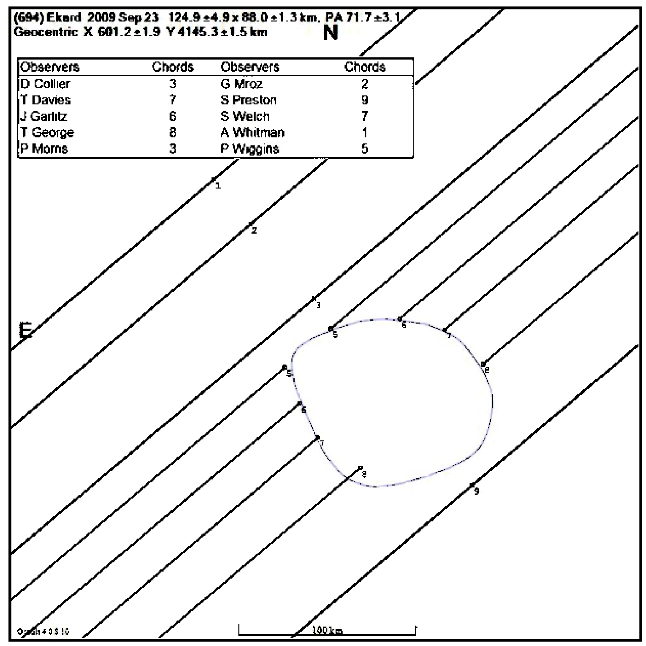

Figure 4. Observed occultation profile for 694 Ekard on 2009 September 23 UT with light curve inversion model (blue).

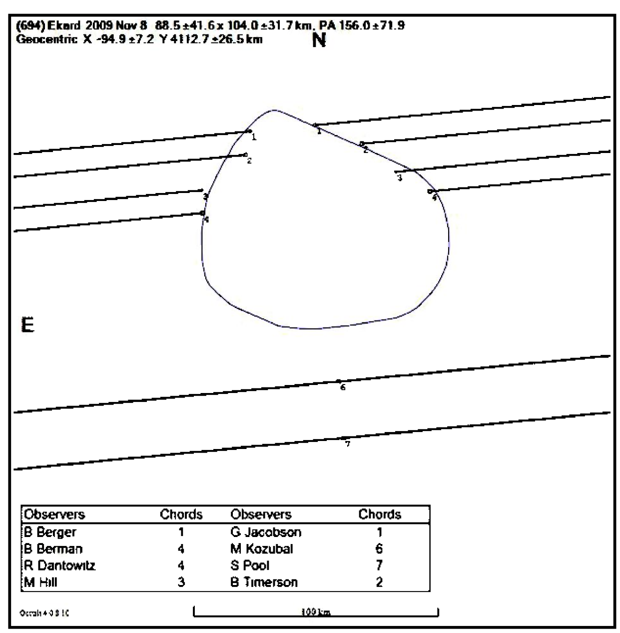

Figure 5. Observed occultation outline for 694 Ekard on 2009 November 8 UT with light curve inversion model (blue).

J. Durech (Durech, 2009) using the results of Torppa (2003) has been superimposed over the observed chords as created in *Occult4* (figures 4 and 5). Maximum duration of 10.89 seconds occurred at station 7, about 3% shorter than predicted. The actual path shifted about one path-width south from what was predicted with the predicted time a few seconds late. The profile produced using *Occult4* and its least squares fit routine shows an ellipse with dimensions of 124.9 ± 4.9 x 88.0 ± 1.3 km. Fitting the irregular shape model provided by Durech to the observations gives a least-squares equivalent diameter of 90 ± 6 km for the asteroid.

Nearly 64 rotational periods later, on 2009 November 8, in twilight at 22:47 UT, Ekard occulted the V magnitude 10.3 star TYC 0528-00946-1 in Aquarius along a path that included central NY to MA. The predicted maximum duration was 4.6 seconds. Six observers provided four positive observations and 2 misses. Of the four positive results, 3 used video techniques and 1 was visual. The maximum observed duration was 4.45 seconds at station 4, about 3% less than predicted. The path showed an approximate ½ path-width shift north. The observed chords from *Occult4* along with the same lightcurve inversion model (Torppa et al. 2003) superimposed, are shown in Figure 5. The *Occult4* profile showed a least squares profile of an ellipse measuring 88.5 ± 41.6 x 104.0 ± 31.7 km. As previously noted, the model provided by Durech gives a least-squares equivalent diameter of 90 ± 6 km for this irregularly shaped asteroid.

Conclusions

Combining observations from a variety of independent sources provides evidence for the shape of asteroids and their orientation during the time of these observations. This can be seen by the excellent agreement between occultation results and inversion models in the case of Ekard. The discrepancy noted in the Terpsichore observations is evidence of the need for more observations of all types. Even including the lightcurve and occultations in late 2009, there are not enough observations of 81 Terpsichore to obtain a reliable model through lightcurve inversion. The observations reported here will contribute toward such a model, but additional future lightcurves and/or occultations with many observed chords are required to complete the model. Future articles will continue to include occultation results in which multiple chords are observed and for which lightcurves and/or inversion models are available.

Acknowledgements

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PERIOD DETERMINATION FOR 4191 ASSESSE

Eduardo Manuel Alvarez
OLASU
Costanera Sur 559, Salto 50.000, URUGUAY
olasu@adinet.com.uy

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Lightcurve analysis for 4191 Assesse was performed from observations during its 2010 opposition. The synodic rotation period was found to be 5.6489 ± 0.0003 h and the lightcurve amplitude was 0.70 ± 0.09 mag.

Unfiltered CCD photometric observations of asteroid 4191 Assesse were obtained at the Observatorio Los Algarrobos, Salto, Uruguay (MPC Code I38), from 2010 May to June. It was selected among the "Potential Lightcurve Targets 2010 April - June" list that appeared in the Collaborative Asteroid Lightcurve Link (CALL) web-site (Warner, 2009) due to having a favorable sky location, a