THE MINOR PLANET BULLETIN

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EDITORIAL: THE MINOR PLANET BULLETIN AT 40

With this issue, the *Minor Planet Bulletin* and the Minor Planets Section of the Association of Lunar and Planetary Observers commemorate their 40th year. (Official founding was in mid-1973.) A retrospective from the Founder, Professor Richard G. Hodgson appears below. Additional retrospectives and insights into the Section and the *Bulletin* appear in the back pages of this issue. (See pages 48–53.) Included herein are a review by Professor Frederick Pilcher, Section Recorder for 30 years. Notes from the *MPB* Distributor for 30 years, Derald Nye, and the *MPB* Producer Robert Werner (28 years) further the historical inside view. Brian Warner's view as the "Minor Planet Observer" and as Assistant Editor (8 years) broaden the perspectives. As an *MPB* subscriber since Volume 1 (and Editor since Volume 10), I simply note the personal and professional pleasure of interacting closely with these volunteering individuals over twoscore years and the pleasure of becoming familiar with and encouraging both new and seasoned observers worldwide. My role is simply one of "giving back" for the encouragement I received as a student entering the field. The activities and success of the Minor Planet Section speak for themselves through the increasingly filled pages of the *Minor Planet Bulletin*, as charted on page 53. Hats-off to Professor Hodgson's founding vision come true! Most of all, credit goes to the observers who fill these pages with their observations that fuel the science of understanding these small worlds.

Richard P. Binzel, Editor

THE EARLY YEARS OF THE MINOR PLANET BULLETIN

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The founding of the Minor Planets Section and *The Minor Planet Bulletin* are recollected, including their earliest sense of purpose and aspirations.

Neither the British Astronomical Association (BAA) nor the Association of Lunar and Planetary Observers (ALPO) had ever had an observing section devoted to the study of asteroids (or minor planets as they were often called). As I wrote in 1973 (Hodgson 1973), when it came to the subject of amateur astronomers and asteroids, the view from the 1950s and 1960s could be summed up as follows: "Most would have agreed with the dictum of the late J. B. Sidgwick (1961; p. 185), 'Apart from interest of tracking down and identifying the brighter asteroids, and as objects of photography, they offer little scope for amateur observation.'" As years passed from the 1960s into the 1970s, telescopes and other equipment (cameras, calculators, computers) improved and a growing number of serious amateur astronomers felt J. B. Sidgwick's dictum no longer applied.

Early in 1973, under the leadership of its Director Walter Haas, the ALPO decided to establish an Asteroids or Minor Planets Section. In the year or two prior I (and I suspect several others) had been urging formation of such a section. I was delighted to receive Walter's invitation to head up the new section as Recorder. (I had previously been Mercury Recorder.) In those days the smaller, non-comet, non-satellite Solar System objects were called "asteroids" and "minor planets" interchangeably in English. Americans tended to use "asteroids" more frequently; Eurasians inclined more to "minor planets." Thinking more globally, and influenced by the prior existence of the IAU Minor Planet Center (MPC) at the Cincinnati Observatory until 1978 (then moved to Cambridge, MA) and the publication *Minor Planet Circulars*, I chose the name "Minor Planets Section." Under the old astronomical definition of the time (prior to the 2006 IAU revision) anything that orbited the Sun and was not a comet could properly be called a planet – size did not matter. (One will note the frequent use of the word "planet" in early Section papers.)

Shortly after becoming Recorder, I decided if we were to stimulate member interest we needed to make reports not only in the *Strolling Astronomer* (Journal of the ALPO), but also we needed to publish more rapidly and frequently in a separately subscribed section journal. In the latter, expedited appeals for observations of unusual minor planets, some newly discovered, others long lost and just rediscovered, could be made and findings reported. I chose to call the new journal the *Minor Planet Bulletin* (or "*MPB*" for short). The name and initials did not conflict with any existing astronomical institution or journal. In a letter dated 1973 May 30, a subscription to the new *MPB* was offered to ALPO members. In that letter, I wrote:

> "I take the view that valuable scientific work has…and will be done by…(1) professional astronomers using the facilities of large universities and advanced institutes, (2) college instructors and their students using more modest equipment, but in a distinctly disciplined way, and (3) well read and well disciplined advanced amateur astronomers, using their own equipment, who wish to contribute to our knowledge of minor planets. While the professional astronomers…will probably publish in *Icarus* and similar journals…given the limited space available in such journals, those in groups 2 and 3…need more opportunity to report and discuss their work. Publications of observations and papers on minor planets by members of all three groups will be a major task—perhaps in time the major task—of the *Minor Planet Bulletin*. … Highly technical papers should continue to be directed toward journals like *Icarus* etc., because of their wider readership among research astronomers; nevertheless there are many studies which deserve publication which do not at present get to circulate. At least this is the view of the Section Recorder; whether this view is correct should be discovered in time."

Volume 1, Number 1 of the *MPB* appeared as a quarterly journal in July 1973. Copies of the new journal were circulated not only to ALPO members, but also to *Sky & Telescope* and to J. U. Gunter's *Tonight's Asteroids* where the *MPB*'s new existence was reported and recommended to a much wider circle of readers. In like manner we freely supplied copies to Brian G. Marsden, Director of the Minor Planet Center (MPC). He was always very helpful, supplying ephemerides and other news for the *MPB*. On occasion we met in his office in Cambridge, MA. From the very beginning we supplied copies to the Astronomische Rechen-Institut in Heidelberg (then West Germany) so that articles they deemed important could be entered into their definitive *Astronomy and Astrophysics Abstracts* for consultation by readers around the world. I was determined from the start that we do serious, high-quality work, and that we take ourselves seriously. (If you don't, no one else will either!)

Reactions to the first issue of the *MPB* were warm and generous. Dr. Joseph Ashbrook, *Sky & Telescope* editor, praised the project, but in a kind letter, took exception to my suggestion that large asteroids should be checked for possible satellites when at highly favorable oppositions. To him such a search was a waste of time since the gravity fields would be far too weak to retain them. I remained firmly in the "let's look" camp. (From my childhood I had a fantasy that minor moons might be possible and I was reluctant to give up the idea.) Of course the incontrovertible discovery of 243 Ida's moon (named Dactyl) almost two decades later would end the matter – even small asteroids can have tiny satellites (e.g. 1862 Apollo)!

Early *MPB* issues outlined the work of the Minor Planets Section which had quickly become an exciting community of scholars discovering more and more about thousands of small worlds, as well as discussing new observing tools and techniques. Occultation opportunities were reported at a time when their observation had hardly been attempted. Early efforts involving Pallas and Vesta were thwarted by clouds. In the first two years of publication a few inter-issue urgent notices were circulated: (1) the *Minor Planet Memo* sent to all subscribers urging observation of a particular object broadly around the world – usually involving requested positional observations of objects at unusually favorable oppositions close at hand, and (2) the *Minor Planet Alert* sent only to subscribers living near a particular region – usually near an occultation zone. (Narrowing the recipients saved postage money.)

In late 1973 and early 1974 a highly favorable approach of Amor minor planet 887 Alinda focused member attention. Positional observations improved orbital data and future ephemeris predictions. A short article from Clark R. Chapman (Chapman 1974) on "The Impossibility of Observing Asteroid Surfaces" presented compelling evidence that asteroid surface details were too small to be photographed or drawn through any privately owned telescope. The next issue included a paper (Hodgson 1974) which argued that Ceres' density had to be low (<2.0 g/cm^3). This introduced several articles on the possible role of water ice in asteroid composition. Ceres' low albedo (~0.06) indicated a dark surface. Spectral evidence favored favored Ceres having a carbonaceous, insulating regolith. The interior might or might not have differentiated in its early history, but to attain the low density there must be a considerable amount of interior water ice. Most asteroid scholars very much doubted permanent water ice would be stable as close to the Sun as Zone II of the asteroid belt. William W. Watson (Watson 1978) argued alternatively that Ceres' low density might be due, not to water ice, but to voids in the interior rocks. The idea that Ceres (and other Zone II asteroids) might contain significant amounts of interior water ice was strongly opposed until hydrated minerals were discovered on Ceres in the late 1970's. Now in 2012 it has been suggested that Ceres may have more fresh water than Earth (Wikipedia article on Ceres, based in part on results of Rivkin et al. 2006). What a change !

In the year that followed (1974-1975) an increasing number of asteroid scholars made contributions to the *MPB*. Frederick Pilcher, soon to become Assistant Recorder and later Section Recorder, began to collect and analyze positional data submitted by Section members. He also began his annual listings of minor planets that would be at unusually favorable oppositions so as to prompt their observation. Edward Tedesco submitted several papers including a major paper "On the Brightness of Asteroids" (Tedesco 1974). Doug Welch, Rick Binzel, and Joe Patterson reported on the rotation of 18 Melpomene (Welch et al. 1974). Thus Rick Binzel, who was among the charter members of the Minor Planets Section, formally began his long relationship with the *Minor Planet Bulletin*. David Dunham wrote notes urging occultation observations. Many other contributors might be mentioned, of course. Most importantly, this period saw a surge in observer interest.

I can give a little back story on Rick Binzel, now *MPB* Editor for 30 years. He was 15 years old and a high school student when he observed 18 Melpomene (along with fellow high school student Doug Welch; under the direction of Joseph Patterson, now on the faculty of Columbia University). Excluding ALPO and asteroid conferences, Rick was one of a very few *MPB* subscribers I ever met in person. Rick arranged to meet with me on an overnight visit while he and Doug Welch were traveling cross-country during the summer of 1976. (Doug is now an extra-galactic astronomer and professor at McMaster University in Canada.) We enjoyed a clear observing night, talking about a career for Rick studying asteroids. We talked about asteroids being an exploding field in astronomy. I guess it was one of the best sales-pitches I ever made. That fall Rick went on to Macalester College in St. Paul, MN. Four years later he graduated from there majoring in physics-astronomy. Then he went to the University of Texas at Austin for his Ph.D., writing his dissertation on asteroid rotation properties. Not long after he went on to be an Assistant Professor at the Massachusetts Institute of Technology (MIT) where he very soon (it seemed to me) became a tenured Professor of Planetary Science.

Special mention should be made of the great amateur mathematician-astronomer Jean Meeus of Belgium, who was to bring many European readers to our pages. It is a wonder we made any contact with him at all! One day as Editor I received a portion of a mangled, torn letter from Europe. It had been lost and mangled in the mail and somehow had mysteriously found its way to an obscure post office in Louisiana. The postmaster there could make little of the fragment but he did his best. He made out my name and the words "Dordt College" so he put it in an envelope and mailed it to Dordt with my name. It was four weeks old by the time I received it, but I quickly made contact with Meeus. (I was so fearful Meeus would be insulted by my non-reply!) He was soon to provide us with articles like "Least Distances of Apollo and Amor Objects to Planetary Orbits" (Meeus 1975a) and "Calculation of the Magnitude of Asteroids" (Meeus 1975b). Jean Meeus also introduced us to the fine historical studies on asteroids written in French by his friend M.-A. Combes of Paris. Before long Meeus sent us his English translation of the studies for publication in the *MPB*. By 1976 to 1978 about 30% of *MPB* articles and observational papers were originating in Europe. Some contributions were also received from Brazil, Argentina, and Western Australia.

Observing asteroid occultation's became an increasingly important venture for Section members in the latter half of the 1970's. Positional observations of minor planets continued, and slowly ephemeris errors declined as asteroid orbits improved with more frequent observations. The quality and capacity of computers that generated the ephemerides also improved greatly. More precise magnitudes for objects were published as well. In time, positional observations became somewhat less important perhaps, but there were always new objects to track down. Remember: we only knew of about 35 Apollo and Amor objects in 1975; the first Aten object was discovered in early 1976. Now there are thousands !

In 1976 the Editor presented a paper at Boulder, Colorado (and in the *MPB*; Hodgson 1976) renewing discussion that Ceres might contain a considerable amount of water ice. The idea was to remain a minority view for two or three more years, as noted above.

In the late 1970's successful observations of asteroid occultation's of bright distant stars led in some cases to disputed evidence of their having satellites or binary companions. Occultation observations of 532 Herculina suggesting it had a satellite was much disputed in 1978. Debate carried over to the Tucson Asteroid Conference in early 1979. The issue was not clearly settled until 243 Ida was imaged with its satellite by the Galileo spacecraft in 1993. Now we know a great number of them.

The work of the ALPO Minor Planets Section expanded greatly in the mid- and late-1970's. Small teams of members became better organized in their specialties. Prof. Frederick Pilcher continued encouraging favorable opposition observing and reported positional observations for the Section. Alain C. Porter (a young Rhode Island observer, went on to be an expert on elliptical galaxies before he died early of cancer) and Derek Wallentine (later Wallentinsen) encouraged rotation studies based on lightcurve observations. June LoGuirato supplied historical notes of interest. Rick Binzel indexed lightcurves (Binzel 1979). Dr. David Dunham continued encouraging occultation observations on behalf of the International Occultation Timing Association (IOTA). Statistical studies were contributed by Keith Peterson and William Nieuwenhuis. With new research tools and techniques available for both amateurs and for professionals, the Minor Planet Revolution was well underway by 1981. As we all worked together it was also gratifying to see the decades-old gap between serious amateur and professional astronomers closing steadily, an old dream come true.

In the early 1980's, after a year's leave of absence in the U.S. Virgin Islands living with my family on a small sailboat under southern stars, the teaching demands of the college became extremely heavy on me. The two-semester "Introduction to Astronomy" course had over 125 students enrolled. I had a load of fours courses each semester. I realized I had not enough quality time available to edit the *MPB*. I resigned as Recorder of the Section effective 1983 January 15 after ten years of service.

I was very glad Frederick Pilcher became the new (and present) Section Recorder. I thought at that time the *MPB* would come to an end. No one stepped forward to edit it. Then, when no one else did, Rick Binzel offered to do the task. I was overjoyed! The dream did not die, and what a vehicle for lightcurve and rotation analysis the *MPB* has become! Observing teams with participants, both professional and serious amateur from all over Earth crowd its pages with valuable reports. The topics in today's *MPB* may not be as diverse as in the 1970's, but the quality of the work is excellent!

In 1984 the International Astronomical Union (IAU) named a Zone I asteroid "2873 Binzel" for our present *MPB* Editor. At the same time they named "2888 Hodgson" for me. I don't think the Committee noticed it at the time, but 2873 Binzel has a mean distance of 2.238 AU and 2888 Hodgson has a mean distance of 2.257 AU, a difference of 0.019 AU or ~2,842,360 km. This is a distance, but not a great one as Solar System objects go. Thus our namesake asteroids will be going around the Sun fairly much together for tens of millions of years. I can't think of better company!

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ASTRONOMICAL RESEARCH INSTITUTE PHOTOMETIC RESULTS

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The Astronomical Research Institute (ARI) conducts astrometric and photometric studies of asteroids with a concentration on near-Earth objects (NEOs). A 0.76-m autoscope was used for photometric studies of seven asteroids of which two were main-belt targets and five were NEOs, including one potentially hazardous asteroid (PHA). These objects are: 3122 Florence, 3960 Chaliubieju, 5143 Heracles, (6455) 1992 HE, (36284) 2000 DM8, (62128) 2000 SO1, and 2010 LF86.

Photometric CCD data were obtained at Astronomical Research Institute (ARI) using a 0.76-m f/6.8 telescope and SBIG STL-1001E camera with a 1024x1024x24-micron array. This gave a scale of 0.98 arcsec per pixel and 16x16 arcminute field-of-view (FOV). All images were reduced using flat, dark, and bias frames through *CCDsoft* software. All analysis of data was performed through *MPO Canopus*.

3122 Florence (H = 14.2). 3122 is a potentially hazardous asteroid (PHA) in an Amor orbit (q = 1.021 AU) and has a taxonomic class of S (Bus and Binzel, 2002). ARI's four nights of observations confirm the period found by Elenin (2012), our results being P = 2.358 ± 0.001 h and A = 0.25 mag.

3960 Chaliubieju (H = 12.0). 3960 is a main belt asteroid (q = 1.907 AU) with a listed period in the LCDB (Warner *et al.*, 2009) of 3.986 h and amplitude A = 0.27 mag. Three nights of observations during 2011 March confirmed the LCDB listing. Our results indicated a period of P = 3.984 ± 0.002 h and A = 0.30 mag.

5143 Heracles (H = 14.0). 5413 is an Apollo NEO with q = 0.417 AU and a = 1.833 AU. Bus and Binzel (2002) list 5413 as a taxonomic class O. Pilcher *et al.* (2012) reported an extensive study of the asteroid with a lightcurve of P = 2.7064 h. Initial analysis of our data found a different period, P = 2.656 h. The referees pointed out that our data set was comprised of two nights with a 12-day gap and that over that time there was almost exactly a 2 rotation difference between our period and the one found by Pilcher *et al*. This raised the possibility of finding what is called a "rotation alias", meaning that our solution assumed the wrong number of rotations over the span of data. In fact, the period spectrum in the original analysis the Pilcher *et al.* period came in a close second.

We reworked our analysis and found that the data equally fit a period of P = 2.706 ± 0.001 h, in agreement with the Pilcher *et al*. period, and amplitude of A = 0.12 mag. Plots of our data based on each period are provided for comparison. This serves as a cautionary tale that when working with data sets that are well-separated in time, a more critical analysis may be required and, if there is doubt and it is possible, to obtain more data, preferably on two consecutive nights.

(6455) 1992 HE (H = 13.8). 6455 is an Apollo NEO with q = 0.958 AU and a = 2.241 AU. Bus and Binzel (2002) listed 6455 as a taxonomic class S. Brian Skiff (2012) and ARI found the same period during 2012 April. ARI imaged for four nights. The analysis of the resulting data found a period of P = 2.736 ± 0.001 h and amplitude A = 0.22 mag.

(36284) 2000 DM8 (H = 15.0). 36284 is an Apollo NEO with q = 0.662 AU and a = 1.483 AU. Bus and Binzel (2002) gave 36284 a taxonomic class of Sq. ARI imaged the asteroid on two nights in 2011 January which resulted in finding a period of P = 3.848 ± 0.004 h and A = 0.30 mag. This confirmed Brian Skiff's results listed in the LCDB (Skiff, 2011) of P = 3.844 ± 0.001 h.

(62128) 2000 SO1 (H = 12.1). 62128 is a main-belt asteroid with q = 2.441 AU, a = 3.147 AU, and an inclination of i = 26.7°. Analysis of seven nights of observations resulted in a period of P = 6.706 ± 0.002 h and A = 0.40 mag. No previous work on 62128 was found.

2010 LF86 (H = 17.21). 2010 LF86 is an Amor NEO with q = 1.299 AU. ARI imaged for four nights in 2010 December. Analysis results showed a period of P = 4.444 ± 0.001 h and amplitude A = 0.55 mag. No previous work on 2010 LF86 was found.

Acknowledgements

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Information about the Astronomical Research Institute work on near-Earth objects can be found at *http://astro-research-org*. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the National Aeronautics and Space Administration

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UT Date	Δ	r	Phase	Mag
2010-12-14	0.665	1.443	35.89	15.4
2011-01-02	0.692	1.557	26.02	15.3
2011-01-03	0.694	1.563	25.58	15.3
2011-01-04	0.697	1.569	25.16	15.3

Table I. 3122 Observation Parameters.

UT Date	Δ	r	Phase	Mag
2011-03-01	1.178	2.097	13.45	15.0
2011-03-02	1.183	2.100	13.72	15.0
2011-03-03	1.189	2.102	14.00	15.0

Table II. 3960 Observation Parameters.

UT Date	Δ	r	Phase	Mag
2011-11-06	0.497	1.440	20.92	14.2
2011-11-18	0.349	1.291	25.86	13.4

Table III. 5143 Observation Parameters.

UT Date	Δ	r	Phase	Mag
2012-04-12	0.690	1.638	17.66	15.1
2012-04-17	0.662	1.598	20.40	15.0
2012-04-18	0.658	1.590	21.06	15.0
2012-04-25	0.634	1.534	26.41	15.0

Table IV. 6455 Observation Parameters.

UT Date	Δ	r	Phase	Mag
2011-01-30	0.856	1.796	13.70	16.6
2011-01-31	0.844	1.790	12.92	16.6

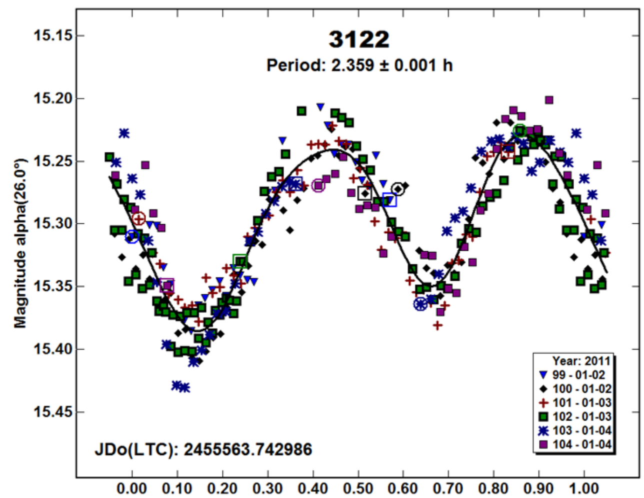
Table V. 36284 Observation Parameters.

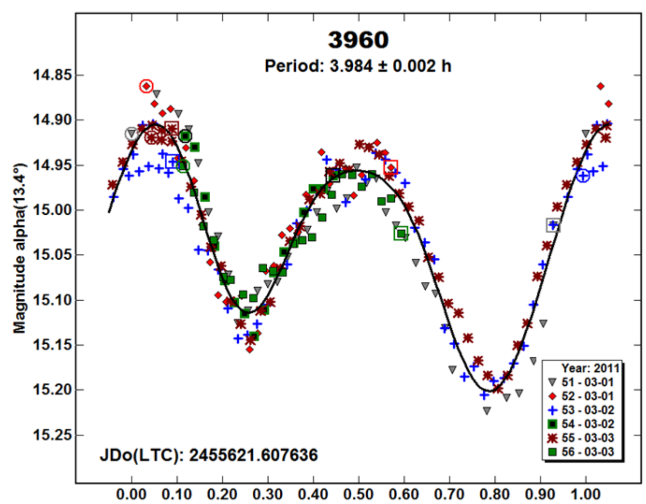
UT Date	Δ	r	Phase	Mag
2011-10-01	1.523	2.442	11.86	15.7
2011-10-04	1.522	2.441	11.77	15.7
2011-10-05	1.523	2.441	11.77	15.7
2011-10-06	1.523	2.441	11.78	15.7
2011-10-07	1.524	2.441	11.81	15.7
2011-10-08	1.525	2.441	11.86	15.7
2011-10-09	1.526	2.441	11.91	15.7

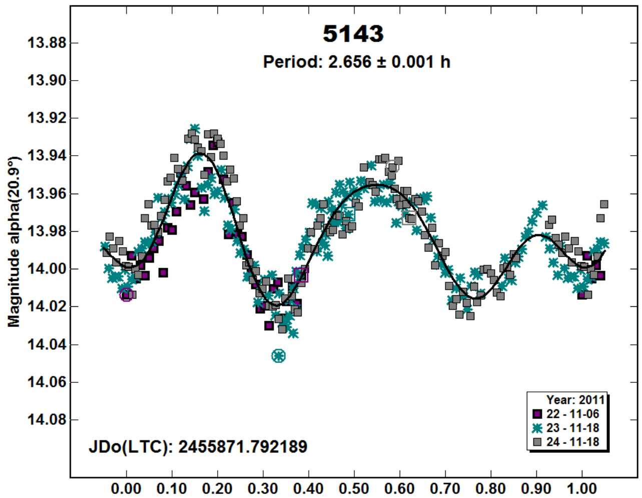
Table VI. 62128 Observation Parameters.

UT Date	Δ	r	Phase	Mag
2010-12-02	0.420	1.302	34.70	17.4
2010-12-06	0.428	1.300	35.77	17.5
2010-12-08	0.432	1.300	36.29	17.5
2010-12-09	0.435	1.300	36.54	17.5

Table VII. 2010 LF86 Observation Parameters



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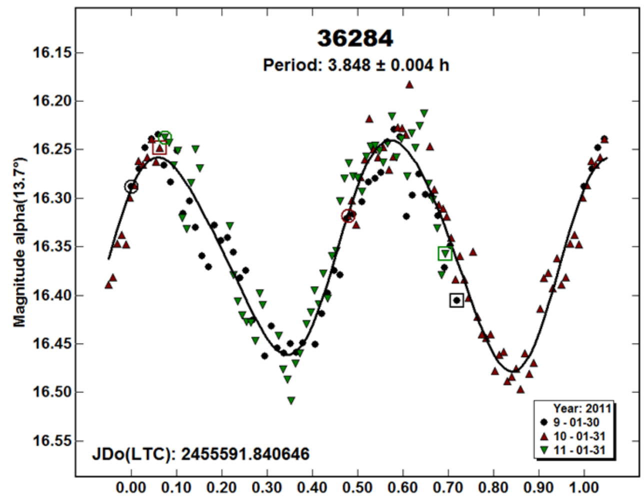
Magnitude alpha(20.9°)
JDo(LTC): 2455871.792189
Year: 2011
22 - 11-06
23 - 11-18
24 - 11-18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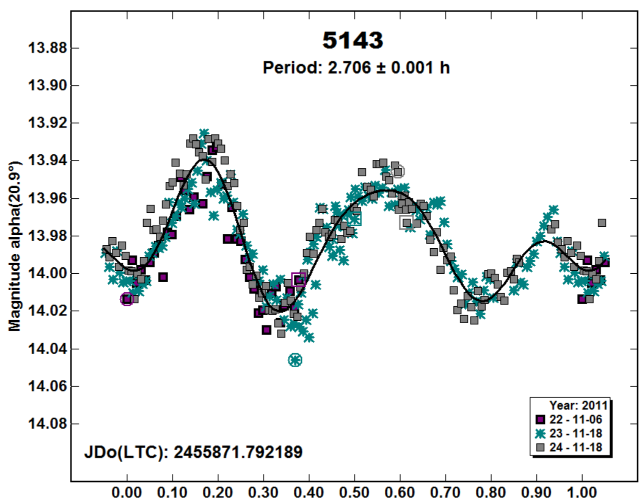
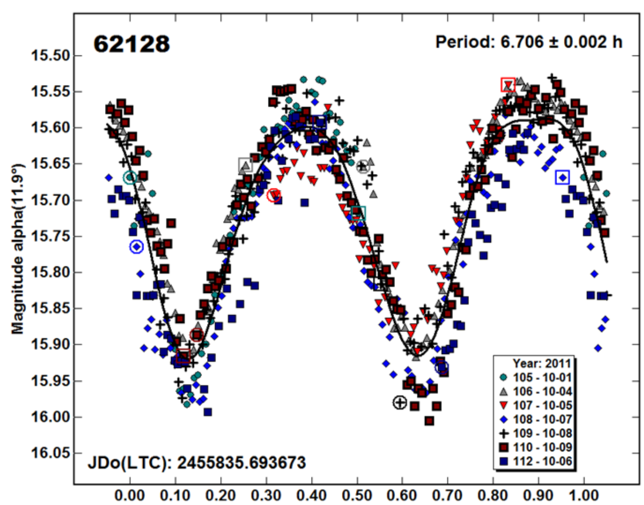
Year: 2011
9 - 01-30
10 - 01-31
11 - 01-31


5143
Period: 2.706 ± 0.001 h
Magnitude alpha(20.9°)
JDo(LTC): 2455871.792189
Year: 2011
22 - 11-06
23 - 11-18
24 - 11-18


62128
Period: 6.706 ± 0.002 h
Magnitude alpha(11.9°)
JDo(LTC): 2455835.693673
Year: 2011
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106 - 10-04
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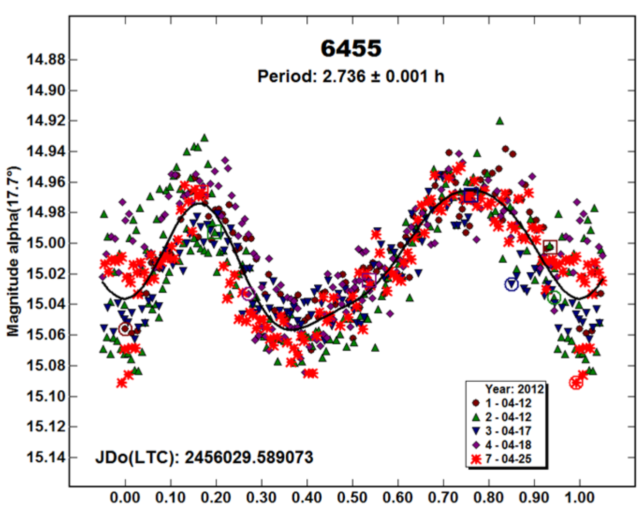
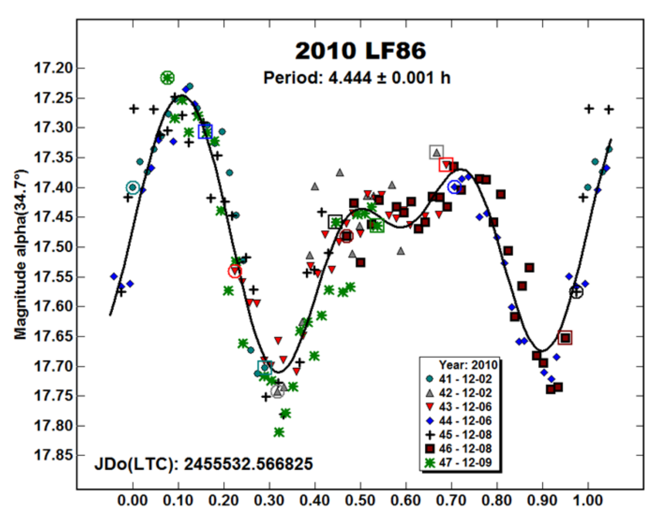
108 - 10-07
109 - 10-08
110 - 10-09
112 - 10-06


6455
Period: 2.736 ± 0.001 h
Magnitude alpha(17.7°)
JDo(LTC): 2456029.589073
Year: 2012
1 - 04-12
2 - 04-12
3 - 04-17
4 - 04-18
7 - 04-25


2010 LF86
Period: 4.444 ± 0.001 h
Magnitude alpha(34.7°)
JDo(LTC): 2455532.566825
Year: 2010
41 - 12-02
42 - 12-02
43 - 12-06
44 - 12-06
45 - 12-08
46 - 12-08
47 - 12-09

DANCES WITH JUPITER- HILDAS AND TROJANS

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(Received: 13 August)

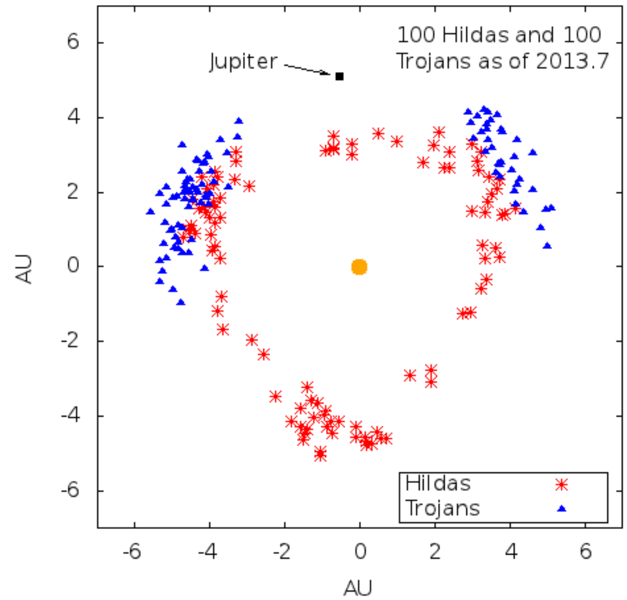
The Hildas and Jovian Trojans are minor bodies closely linked dynamically to Jupiter. Recent ideas on the history of the solar system suggest these objects may be more akin to minor bodies in the outer solar system (Kuiper belt objects) than to the rocky bodies in the main asteroid belt. Here I review the present status of lightcurve observations of these objects. I introduce a web site that has information on observing the Hildas.

The Hildas and Trojans are minor solar system bodies in orbital resonance with Jupiter. The Trojans are in a 1:1 resonance with Jupiter, meaning they orbit with the Sun with same period as Jupiter (11.86 yr). They have average semi-major axes equal to that of Jupiter (5.20 AU). These objects are found near the L4 and L5 Lagrangian points of the Sun-Jupiter system, in two clouds each centered 60 degrees away from Jupiter along its orbit.

The Hildas are in a 3:2 resonance with Jupiter, meaning that they orbit the Sun 3 times for every 2 times that Jupiter does. Therefore the Hildas have orbital periods 2/3 that of Jupiter, 7.91 yr, and they have semi-major axes around 3.95 AU. The Hildas have orbital eccentricities averaging about 0.2, so that a typical Hilda ranges between ~ 3.2 and ~ 4.7 AU from the Sun each orbit. A plot of the positions of the Hildas at any instant in time shows them spread on a quasi-triangular array. Jupiter is always located along one of the sides of the triangle, so that no Hilda approaches Jupiter closer than 1 AU or so. The triangular *pattern* rotates around the Sun with the period of Jupiter, yet each Hilda orbits the Sun every 7.91 yr on its own elliptical orbit. Each Hilda must move through the pattern and is not fixed relative to the pattern. The pattern is due to the fact that the orbital orientation of each Hilda ellipse and its orbital phase is related so that each object is always near perihelion when it crosses the line between the Sun and Jupiter. If there were no such relationship, a Hilda would soon find itself at aphelion near Jupiter, and it would be gravitationally scattered by Jupiter or impact Jupiter.

The above is only an outline of the motions of the Hildas. The motion is much better explained by an animation. I have created a web site (Romanishin 2012) that has an animated gif showing the motion of 100 Hildas and 100 Trojans. One frame of the gif, showing the positions of the Hildas, Trojans, Jupiter and the Sun, projected onto the plane of the Solar System for an arbitrary date, is shown in the accompanying Figure.

<ins>Origin and physical properties</ins>. What are the basic physical properties of the Hildas and Trojans? Recent ideas on the ancient history of the solar system suggest the Jovian Trojans may have been captured into their present orbits from a place of origin much farther from the Sun (Morbidelli *et al*. 2005). This may also be true for the Hildas (Broz *et al.* 2011). This capture may have occurred during a possible dramatic rearrangement of the giant planets about 3.8 billion years ago. This basic idea is called the Nice model (Levison *et al.* 2008). If anything like the Nice model is actually correct, then the Hildas and Trojans may be more akin to the minor bodies in the outer solar system, the Kuiper belt objects and Centaurs, than to the rocky bodies of the main asteroid belt.



Lightcurves of Hildas and Trojans

Lightcurve observations, in particular at multiple epochs so that shapes can be determined, are a simple (and low cost) way to learn something about the physical characteristics of minor bodies. How many of the Hildas and Trojans objects have currently measured lightcurves? As of August 2012, more than 5000 Jovian Trojans and 4000 Hildas are known (JPL Small Body Database Search Engine). To narrow down the numbers to a more manageable size, I have made lists of the 100 Hildas and the 100 Trojans with the lowest absolute mag (H mag) values. These objects, assuming all objects in each class have the same albedo, would be the largest such objects. The lists can be found on my web site. These lists provide samples of objects chosen without regard to the rotational periods of the objects. Measuring periods for such an unbiased sample is important to do proper statistical comparison of rotational properties of different classes of objects. The selection of objects with currently known lightcurves undoubtedly has biases in it. For example, objects with very long periods are probably underrepresented, simply because of the large amount of time needed to measure such objects.

The Hilda100 and Trojan100 lists were compared with the June 2012 Asteroid Lightcurve Database (LCDB) (Warner *et al*., 2012). For the Trojans, 87 objects have a definite value for rotational period listed, and 1 object has a lower limit. The 88 object lightcurves comprise 47 with quality code of 3 or 3-, 37 with code 2, 2- or 2+ and 4 with code 1. For the Hildas, the situation is much less sanguine. Only 44 objects have definite period values, and 8 have lower limits. Quality code 3 or 3- apply to only 22 Hildas, quality code 2, 2- or 2+ to another 22, and 8 have code 1.

The rotational period of a minor body is the most fundamental datum we can learn about a body from its lightcurve. Far more physically valuable is to measure the amplitude and shape of a lightcurve at various places in the orbit of a body. From these, information on the basic shape and rotational pole position of the object can be obtained. In the LCDB, the existence of published data on pole position/shape model is given by the SAM flag. Only

2 of the Trojan100 and 5 of the Hilda100 have published information on pole position/ shape as indicated by a "Y" in the SAM column in LC_SUM_PUB.TXT.

Information for observing Hildas. To assist observers who might wish to observe lightcurves of Hildas, I have prepared tables on my website showing the basic circumstances of the oppositions of each of the Hilda100 objects for the next 8 years. For example, here is the entry for 1911 Schubart, the first object in the Hilda100 list that has no published lightcurve information:

```
1911 Schubart (1973 UD)
2012-Sep-24  δ=+02  mag=15.7  elong=177.9  r=4.1
2013-Nov-21  δ=+21  mag=14.9  elong=178.3  r=3.5
2015-Feb-04  δ=+15  mag=14.7  elong=178.8  r=3.4
2016-Apr-09  δ=-09  mag=15.5  elong=177.8  r=3.9
2017-May-26  δ=-22  mag=16.1  elong=178.5  r=4.4
2018-Jul-05  δ=-22  mag=16.3  elong=179.9  r=4.6
2019-Aug-13  δ=-13  mag=16.2  elong=178.8  r=4.5
```

The first column gives the date on which the object has the greatest elongation angle from the Sun. This is very close to the instant of opposition. The second column (δ) gives the declination of the object on the date in column 1. The third column gives an estimate of the apparent mag of the object. The fourth column is the solar elongation angle in degrees and the last column is the heliocentric distance of the object in AU. Perusal of columns 2 and 3 will quickly allow an observer to find objects that might be bright enough and at an acceptable declination for their observatory. All data comes from the JPL online ephemeris generator (JPL Horizons).

Final words. The Hildas and Trojans are interesting minor bodies that may help delineate an important ancient era in the history of the solar system. Lightcurve observations, particularly those that can yield shapes, are a practical way to study these objects. I hope that web site I have developed will help encourage observers to observe these objects, particularly the Hildas.

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JPL Small Body Database Search Engine *http://ssd.jpl.nasa.gov/sbdb_query.cgi*

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LIGHTCURVES FOR 1896 BEER, 2574 LADOGA, 3301 JANSJE, 3339 TRESHNIKOV, 3833 CALINGASTA, 3899 WICHTERLE, 4106 NADA, 4801 OHRE, 4808 BALLAERO, AND (8487) 1989 SQ

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Lightcurve observations have yielded period determinations for the following asteroids: 1896 Beer, 2574 Ladoga, 3301 Jansje, 3339 Treshnikov, 3833 Calingasta, 3899 Wichterle, 4106 Nada, 4801 Ohre, 4808 Ballaero, and (8487) 1989 SQ.

Photometric data for ten asteroids were obtained at Barnes Ridge Observatory located in northern California, USA, using a 0.43-m PlaneWave f/6.8 corrected Dall-Kirkham astrograph and Apogee U9 camera. The camera was binned 2x2 with a resulting image scale of 1.26 arc-seconds per pixel. All image exposures were 210 seconds taken through a photometric clear filter. All images were obtained with *MaxIm DL* V5 driven by *ACP* V6 and analyzed using *MPO Canopus* v10.4 (Warner, 2011). All comparison stars and asteroid targets had an SNR at least 100.

1896 Beer. Data were collected from 2011 October 1 through November 15 resulting in 10 data sets totaling 796 data points. 1896 Beer was tracked through 330.89 revolutions. A period of 3.3278 ± 0.0001 h was determined with a peak-to-peak amplitude of 0.40 mag. *H* and *G* values were calculated for phase angles of 4.01 through 21.14 degrees resulting in H = 13.990 ± 0.042 and G = 0.158 ± 0.061.

2574 Ladoga. Data were collected from 2011 October 20 through October 30 resulting in 8 data sets totaling 688 data points. 2574 Ladoga was tracked through 8.94 revolutions. A period of 27.240 ± 0.008 h was determined with a peak-to-peak amplitude of 0.26 mag.

3301 Jansje. Data were collected from 2012 June 6 through July 5 resulting in 8 data sets totaling 296 data points. This was a particularly difficult target because of its location in the middle of the northern Milky Way. Therefore many data points had to be rejected because the asteroid crossed background stars, although the StarBGone feature of Canopus was of great help. 3301 Jansje was tracked through 40.78 revolutions. A period of 9.4340 ± 0.0006 h was determined with a peak-to-peak amplitude of 0.70 mag.

3339 Treshnikov. Data were collected from 2012 May 9 through July 1 resulting in 18 data sets totaling 995 data points. 3339 Treshnikov was tracked through 69.44 revolutions. A period of 18.2947 ± 0.0006 h was determined with a peak-to-peak amplitude of 0.30 mag.

3833 Calingasta. Data were collected from 2010 August 13 through September 15 resulting in 19 data sets totaling 847 data points. 3833 Calingasta was tracked through 4.06 revolutions. A period of 195.2 ± 0.1 h was determined with a peak-to-peak amplitude of approximately 0.8 mag. A lightcurve for 3833 Calingasta previously published by Carbognani (2011) had a period of 38.61 ± 0.05 h. It is felt that the period presented here is more secure due to the additional coverage. Carbognani reported four data sets whereas this reported period resulted from 19 data sets with reasonable coverage of the four peaks. Due to the extremely long rotation period of this asteroid, only small fractions of the period were able to be collected during each session and nightly delta magnitude compensations could not be applied. Therefore the period error may be greater than implied.

<u>3899 Wichterle.</u> Data were collected from 2011 December 25 through 2012 January 17 resulting in 5 data sets totaling 381 data points. 3899 Wichterle was tracked through 94.66 revolutions. A period of 5.8572 ± 0.0001 h was determined with a peak-to-peak amplitude of 0.60 mag.

<u>4106 Nada.</u> Data were collected from 2012 April 20 through May 10 resulting in 7 data sets totaling 558 data points. 4106 Nada was tracked through 83.12 revolutions. A period of 5.8330 ± 0.0001 h was determined with a peak-to-peak amplitude of 0.60 mag. *H* and *G* values were calculated for phase angles of 4.37 through 13.33 degrees resulting in *H* = 12.477 ± 0.081 and *G* = 0.301 ± 0.128. Stephens (2012) reported a period of 5.832 ± 0.002 h using 3 data sets. Given that these are synodic periods, which can vary from apparition to apparition, the two solutions are statistically the same.

<u>4801 Ohre.</u> Data were collected from 2012 January 13 through February 17 resulting in 9 data sets totaling 523 data points. 4801 Ohre was tracked through 27.57 revolutions. Data were previously published by Klinglesmith (2012), who observed from 2012 January 1 through January 31. These overlapped the data collection dates reported here by about 2 weeks. The Klinglesmith data were analyzed using comp star R magnitudes. Combining data sets and using comp star R magnitudes, a period of 32.000 ± 0.002 h was determined with a peak-to-peak amplitude of 0.50 mag. Combining the two data sets resulted in a total of 1370 data points and provided a more secure period solution.

<u>4808 Ballaero.</u> Data were collected from 2011 December 18 through December 24 resulting in 5 data sets totaling 499 data points. 4808 Ballaero was tracked through 19.85 revolutions. A period of 8.8996 ± 0.0007 h was determined with a peak-to-peak amplitude of 0.30 mag.

<u>(8487) 1989 SQ.</u> Data were collected from 2011 November 17 through December 14 resulting in 9 data sets totaling 546 data points. (8487) 1989 SQ was tracked through 69.42 revolutions. A period of 9.4323 ± 0.0004 h was determined with a peak-to-peak amplitude of 0.25 mag.

Acknowledgements

The author thanks Daniel Klinglesmith for permission to use his data for 4801 Ohre to obtain a more secure period. The author also gives thanks to Brian Warner for his assistance in combining data sets for 4801 Ohre period analysis.

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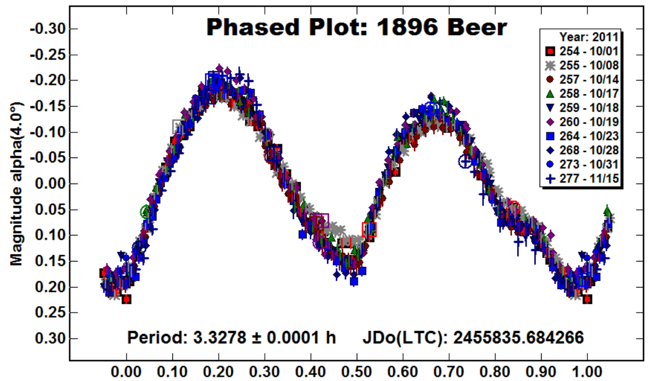

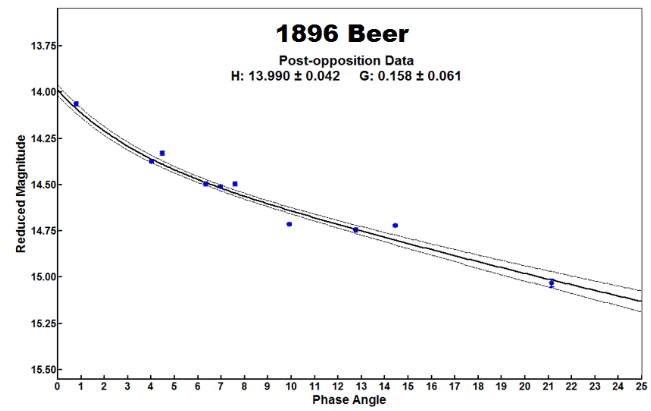

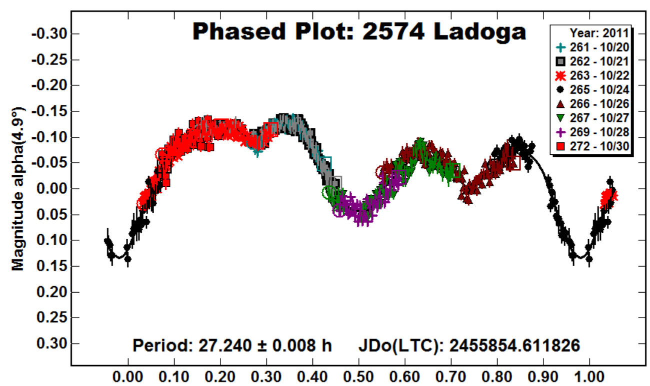

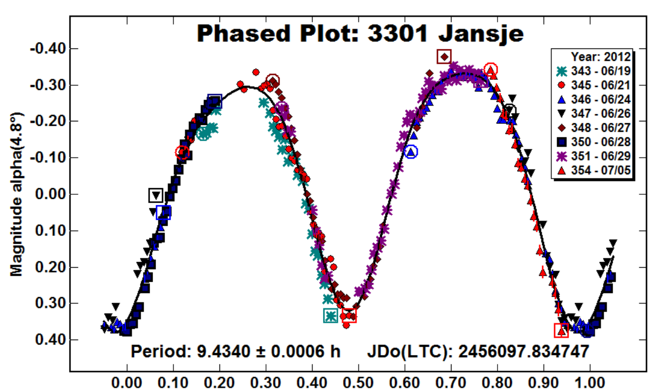

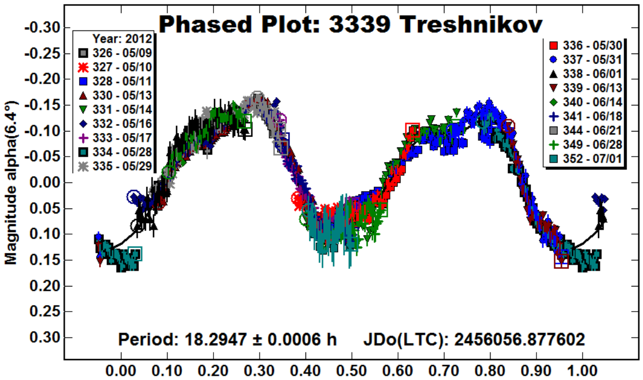
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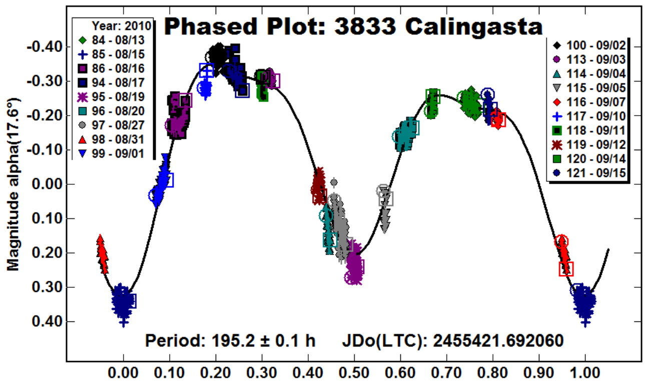
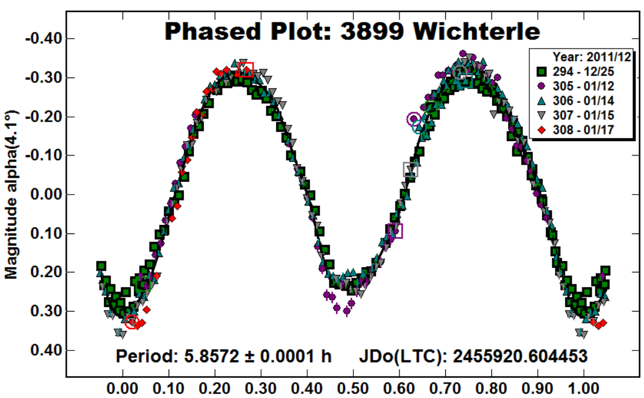
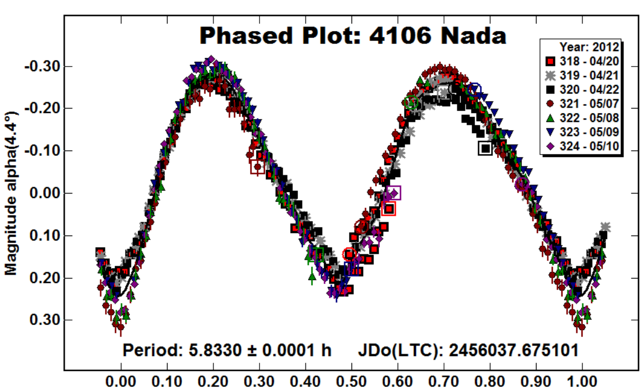
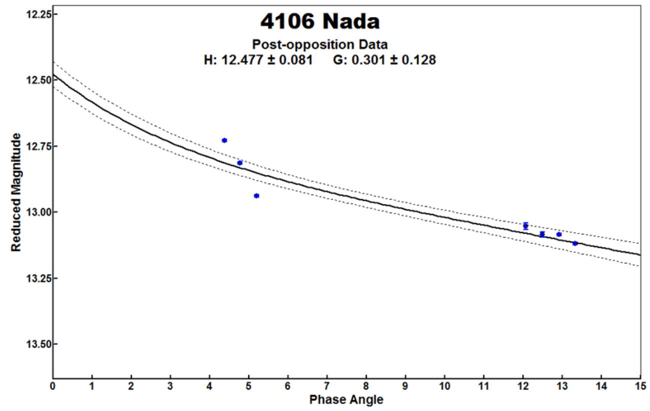
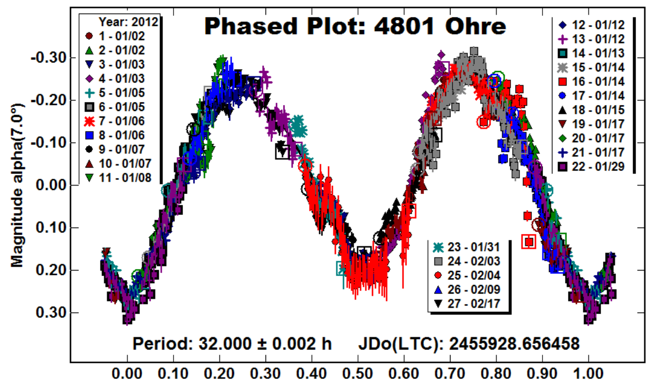
Year: 2012
326 - 05/09
327 - 05/10
328 - 05/11
330 - 05/13
331 - 05/14
332 - 05/16
333 - 05/17
334 - 05/28
335 - 05/29
336 - 05/30
337 - 05/31
338 - 06/01
339 - 06/13
340 - 06/14
341 - 06/18
344 - 06/21
349 - 06/28
352 - 07/01
Magnitude alpha(6.4°)
Period: 18.2947 ± 0.0006 h JDo(LTC): 2456056.877602


Phased Plot: 3833 Calingasta
Year: 2010
84 - 08/13
85 - 08/15
86 - 08/16
94 - 08/17
95 - 08/19
96 - 08/20
97 - 08/27
98 - 08/31
99 - 09/01
100 - 09/02
113 - 09/03
114 - 09/04
115 - 09/05
116 - 09/07
117 - 09/10
118 - 09/11
119 - 09/12
120 - 09/14
121 - 09/15
Magnitude alpha(17.6°)
Period: 195.2 ± 0.1 h JDo(LTC): 2455421.692060


Phased Plot: 3899 Wichterle
Year: 2011/12
294 - 12/25
305 - 01/12
306 - 01/14
307 - 01/15
308 - 01/17
Magnitude alpha(4.1°)
Period: 5.8572 ± 0.0001 h JDo(LTC): 2455920.604453


Phased Plot: 4106 Nada
Year: 2012
318 - 04/20
319 - 04/21
320 - 04/22
321 - 05/07
322 - 05/08
323 - 05/09
324 - 05/10
Magnitude alpha(4.4°)
Period: 5.8330 ± 0.0001 h JDo(LTC): 2456037.675101


4106 Nada
Post-opposition Data
H: 12.477 ± 0.081 G: 0.301 ± 0.128
Reduced Magnitude
Phase Angle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Year: 2012
1 - 01/02
2 - 01/02
3 - 01/03
4 - 01/03
5 - 01/05
6 - 01/05
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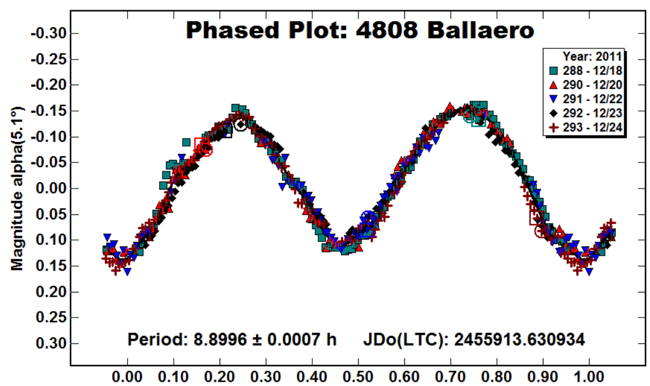
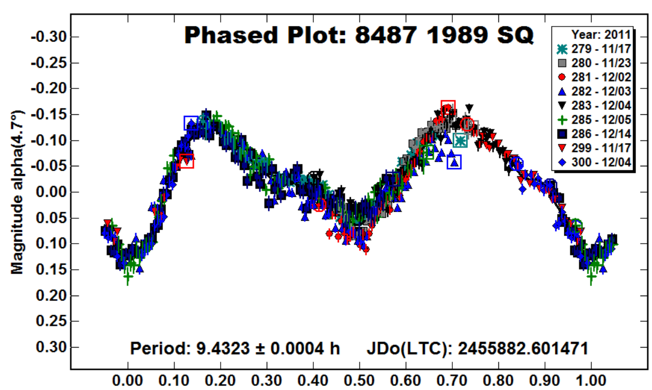
8 - 01/06
9 - 01/07
10 - 01/07
11 - 01/08
12 - 01/12
13 - 01/12
14 - 01/13
15 - 01/14
16 - 01/14
17 - 01/14
18 - 01/15
19 - 01/17
20 - 01/17
21 - 01/17
22 - 01/29
23 - 01/31
24 - 02/03
25 - 02/04
26 - 02/09
27 - 02/17
Magnitude alpha(7.0°)
Period: 32.000 ± 0.002 h JDo(LTC): 2455928.656458


Phased Plot: 4808 Ballaero
Year: 2011
288 - 12/18
290 - 12/20
291 - 12/22
292 - 12/23
293 - 12/24
Magnitude alpha(5.1°)
Period: 8.8996 ± 0.0007 h JDo(LTC): 2455913.630934


Phased Plot: 8487 1989 SQ
Year: 2011
279 - 11/17
280 - 11/23
281 - 12/02
282 - 12/03
283 - 12/04
285 - 12/05
286 - 12/14
299 - 11/17
300 - 12/04
Magnitude alpha(4.7°)
Period: 9.4323 ± 0.0004 h JDo(LTC): 2455882.601471

LIGHTCURVE ANALYSIS OF 1110 JAROSLAWA AND 13643 TAKUSHI

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(Received: 1 August)

Period and amplitude results for asteroids 1110 Jaroslawa and 13643 Takushi are presented. Both asteroids were found to be fairly slow rotators with periods that were near-simple multiples of an Earth day. International collaboration is requested at future oppositions.

The Preston Gott Observatory is the main astronomical facility of the Texas Tech University. Located about 20 km north of Lubbock, the main instrument is a 0.5-m f/6.8 Dall-Kirkam Cassegrain. An SBIG STL-1001E CCD was used with this telescope. All images were unfiltered and were reduced with dark frames and sky flats. Image analysis was accomplished using differential aperture photometry with *MPO Canopus*. Period analysis was also done in *MPO Canopus*, which implements the FALC algorithm developed by Alan Harris (Harris *et al.*, 1989). Differential magnitudes were calculated using reference stars from the USNO-A 2.0 catalog and the UCAC2 catalog.

Results are summarized in the table below and the lightcurve plots. Column 3 of the table gives the range of dates of observations while column 4 gives the number of nights on which observations were undertaken.

<u>1110 Jaroslawa</u>. I had previously observed asteroid 1110 Jaroslawa in 2004 June (Clark, 2007). The observations from that time were inconclusive due to the period appearing to be a simple fraction of a day, but a possible single-peak period of 9.408 hours was suggested. The current results rule that period out completely. Instead the period derived from the latest observations is around 94.447 hours. Incorporating the 2004 data into the lightcurve analysis (second plot) results in a period of 94.432 hours. The total amplitude was about 0.8 mag. However, this result is still tentative since only a small portion of the lightcurve was obtained each night.

The asteroid next reaches opposition in 2013 February, when it will be located at –2° declination in the constellation Sextans and at a magnitude of V ~ 15. This means it will be easily observed from both Northern and Southern Hemispheres. Accordingly, I am requesting collaboration with observers in Europe and Australia during late December-early February with the aim of obtaining continuous coverage of the rotation period. Interested observers are invited to contact me indicating their interest.

<u>13643 Takushi.</u> This asteroid also proved to be a relatively slow rotator. The period derived from 5 nights of observations was around 83.838 hours with a possible amplitude of around 1.00 mag. However these results are tentative since no definite maximum or minimum was observed.

The asteroid next reaches opposition in late 2013 May. At that time, it will be located at about –27° declination and so best observed from the Southern Hemisphere. Unfortunately, although the asteroid will be a moderately bright at V ~ 16.2, it will be located in the very dense star fields of northern Scorpius, making photometry difficult. Nevertheless, if any observers are interested in attempting a coordinated observational campaign during 2013 May, they are welcome to contact me.

Acknowledgments

I would like to thank Brian Warner for all of his work with the program *MPO Canopus* and for his efforts in maintaining the "CALL" website.

References

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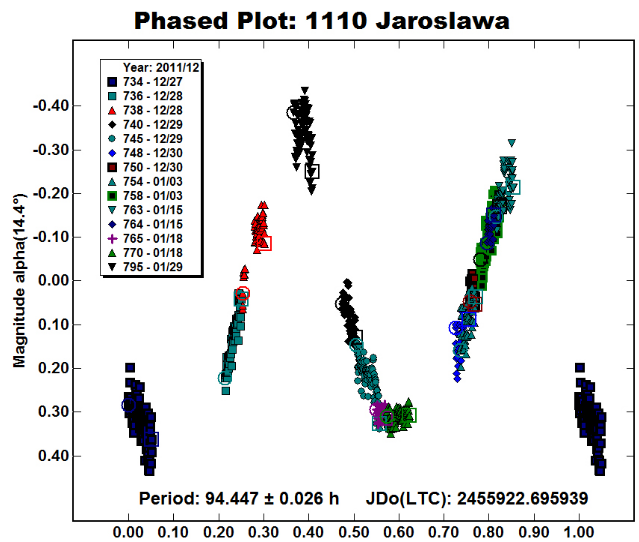
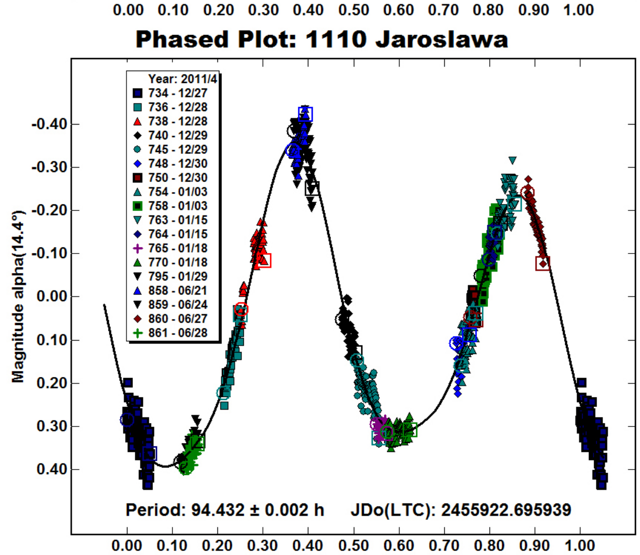
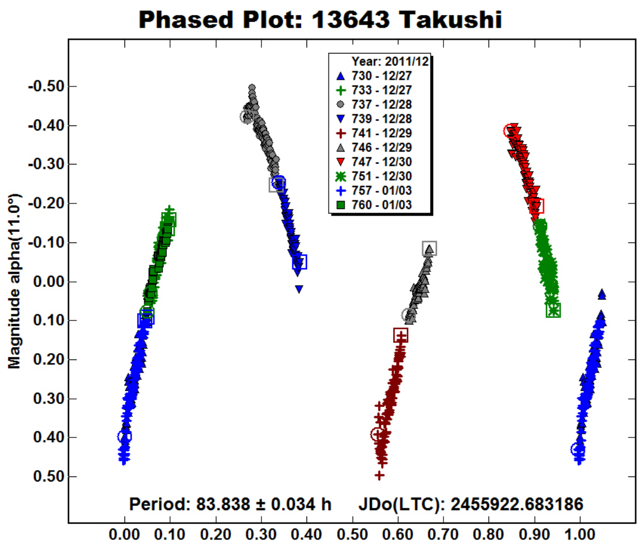




#	Name	Date Range	Nights	Per (h)	Error (h)	Amplitude	Error
1110	Jaroslawa	Dec 27, 2011 - Jan 29, 2012	8	94.432	0.002	0.8	0.1
13643	Takushi	Dec 27, 2011 - Jan 03, 2012	5	83.838	0.034	1.00	0.1



ASTEROID LIGHTCURVE ANALYSIS AT RIVERLAND DINGO OBSERVATORY (RDO): 501 URHIXIDUR, 1897 HIND, 1928 SUMMA, 6261 CHIONE AND (68216) 2001 CV26

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(Received: October 15)

Lightcurves for five asteroids selected from the *Collaborative Asteroid Lightcurve Link* (CALL) were obtained at Riverland Dingo Observatory (RDO) from 2012 July-September: 501 Urhixidur, 1897 Hind, 1928 Summa, 6261 Chione, and (68216) 2001 CV26.

The observations reported here were all obtained using a 0.41-m f/9 Ritchey-Chretien telescope, SBIG STL-1001E CCD camera, and either clear or Johnson-Cousins V filter, as indicated. All images were bias, dark, and flat field corrected and have an image scale of 1.35 arc seconds per pixel. Differential photometry measurements were made in *MPO Canopus* (Bdw Publishing). V magnitudes for comparison stars were extracted from the *AAVSO Photometric All-Sky Survey (APASS)* catalog.

The Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) does not contain any previously reported results for asteroid 6261 Chione. Previously reported results for the other asteroids are referred to below.

501 Urhixidur is a main-belt asteroid discovered by Wolf in Heidelberg in 1903. Lagerkvist (1992) reported a period of 15 h, which is rated U = 1 in the LCDB. A total of 826 data points were obtained over seven nights using a Johnson-Cousins V filter during the period 2012 July 5-24, when the asteroid's average magnitude was 14.0 and average SNR was 173. The lightcurve shows a period of 13.1743 ± 0.0008 h and amplitude of 0.14 ± 0.01 mag.

1897 Hind is a main-belt asteroid discovered by Kohoutek in Bergedorf in 1971. Behrend (2005) found a period of 0.82 ± 0.01 h. This is given U = 1 in the LCDB. A total of 159 data points were obtained using a Johnson Cousins V filter on 2012 July 25 and August 9, with an average magnitude of 15.5 and average SNR of 75. The lightcurve shows a period of 2.6336 ± 0.0001 h and amplitude of 0.09 ± 0.01 mag.

1928 Summa is a main-belt asteroid discovered by Vaisala in Turku in 1938. Binzel (1987) reported a period of 9.66 h. The LCDB rated this U = 1. A total of 843 data points were obtained using a clear filter over five nights during the period 2012 September 3-10, with an average magnitude of 15.2 and average SNR of 83. The lightcurve shows a period of 6.8549 ± 0.0006 h and amplitude of 0.18 ± 0.01 mag.

6261 Chione is a Mars-crossing asteroid discovered by Schuster in La Silla in 1976. A total of 377 data points were obtained using a clear filter over five nights during the period 2012 September 18-25. The average magnitude was 17.0 and average SNR ~ 36. The lightcurve shows a period of 5.3334 ± 0.0003 h and amplitude of 0.75 ± 0.04 mag.

(68216) 2001 CV26 is a near-Earth Apollo asteroid discovered by LINEAR in Socorro in 2001. With a minimum orbit intersection distance (MOID) of 0.024 AU, it has been flagged as a potentially hazardous asteroid (PHA) by the Minor Planet Center. There are two entries on the LCDB. The first reports a period of 2.409 ± 0.021 h, U = 3 (Hicks, 2010). The second reports a period of 2.427 ± 0.004 h, U = 3 (Polishook, 2012). A total of 380 data points were obtained using a clear filter over five nights during the period 2012 August 20 to September 2, with an average magnitude of 16.6 and average SNR of 34. The lightcurve shows a period of 2.4290 ± 0.0002 h and amplitude of 0.23 ± 0.04 mag.

Acknowledgements

The measurements reported make use of the *AAVSO Photometric All-Sky Survey (APASS)* catalog, which is funded by the Robert Martin Ayers Sciences Fund. Thank you to Darren Wallace of RDO and his collaborators at New Mexico Skies for maintaining the equipment in Australia.

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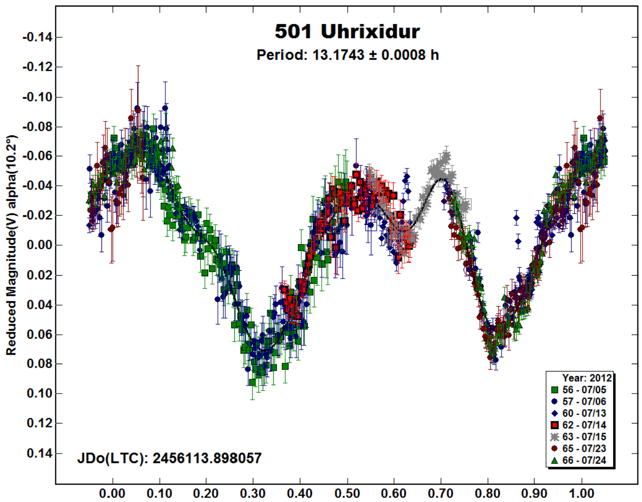

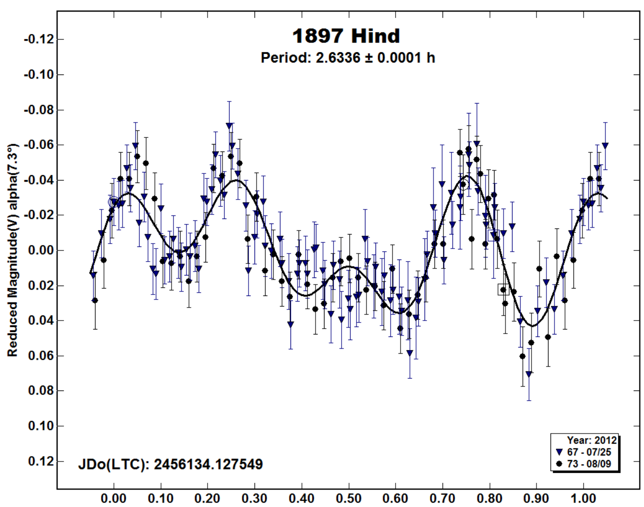

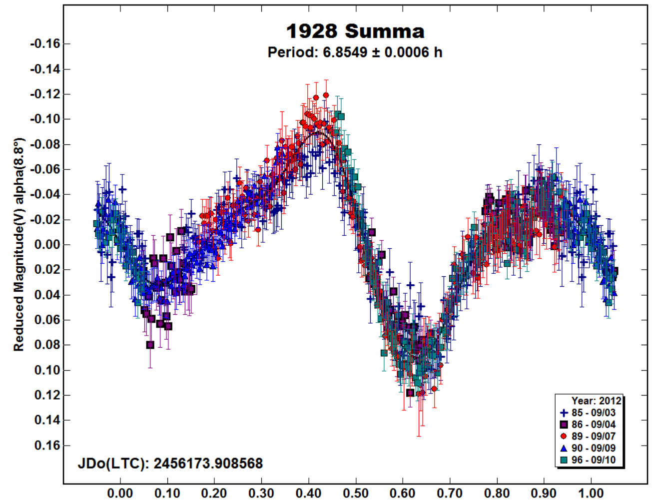

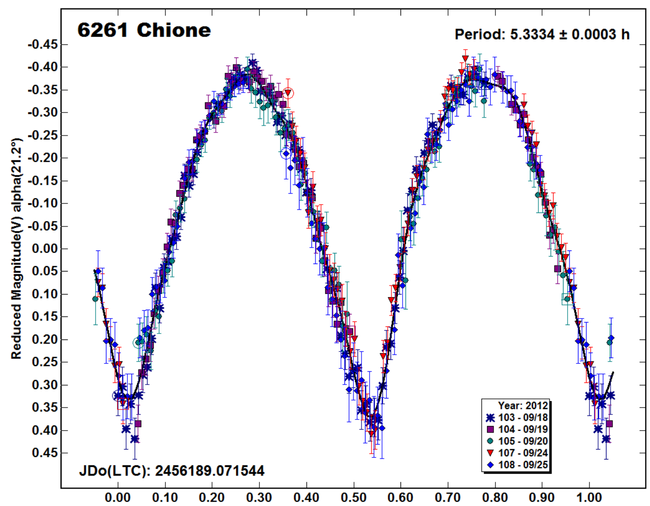

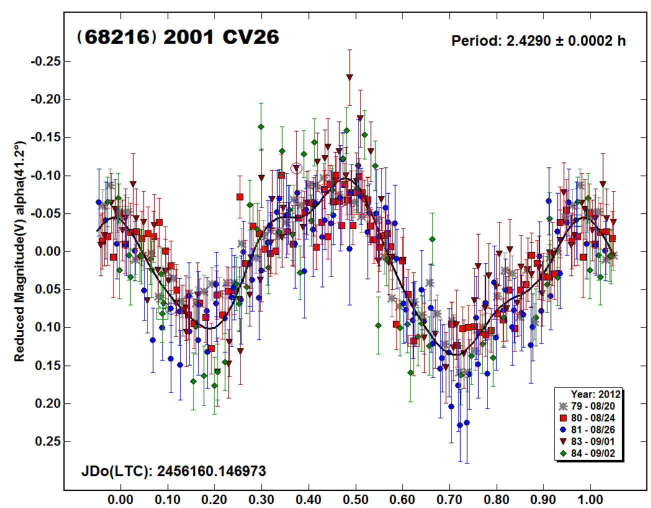

ROTATION PERIODS OF 1660 WOOD, 7173 SEPKOSKI, 12738 SATOSHIMIKI, AND (23233) 2000 WM72

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We present rotation periods of four asteroids: 1660 Wood, 7173 Sepkoski, 12738 Satoshimiki, and (23233) 2000 WM72. The observations were undertaken using the SARA (Southeastern Association for Research in Astronomy) South telescope, located in Cerro Tololo Inter-American Observatory in Chile, from 2011 December to 2012 April. The following synodic periods were found: 1660 Wood, P = 6.8088 ± 0.0002 h; 7173 Sepkoski, P = 2.44 ± 0.02 h; 12738 Satoshimiki, P = 8.708 ± 0.001 h; and (23233) 2000 WM72, P = 3.732 ± 0.003 h.

All observational data reported here were obtained using the remotely-operated 0.61-m SARA South telescope located at the Cerro Tololo Inter-American Observatory in Chile. The telescope has an effective focal ratio of f/13.5. Coupled to a QSI 683s CCD camera, this resulted in a resolution of 0.41 arcsec/pixel (binned 3×3) and field of view (FOV) = 7.51×5.70 arcminutes. Bessell R or IR blocking (clear) filters were used when taking images. The camera temperatures were set to between –25°C and –35°C. Image acquisition was done with *MaxIm DL*. All images were reduced with master bias, dark, and flat frames. All calibration frames were created using *IDL*. *MPO Canopus* was used for analyzing the processed images and extracting the periods from the lightcurves. The asteroids were selected from the list of asteroid photometry opportunities published on the Collaborative Asteroid Lightcurve Link (CALL) website (Warner *et al.*, 2008)

1660 Wood. We observed this potentially hazardous asteroid (PHA) for three nights from 2012 Jan 15 to Mar 26. We obtained a period *P* = 6.8088 ± 0.0002 h. Its amplitude (*A*) steadily increased from about 0.16 ± 0.02 mag in January to 0.26 ± 0.02 mag in March. The large time span in the observations and the variation in the observed amplitudes may prove to be useful for future shape modeling. Our period is consistent with 6.8090 ± 0.0002 h obtained by Oey and Alvarez (2012), who carried out their studies during the same observation season.

7173 Sepkoski. We selected this asteroid to accumulate lightcurve data for future shape modeling. We observed it on the evening of 2012 Mar 26 and obtained a period *P* = 2.44 ± 0.02 h and an amplitude *A* = 0.20 ± 0.05 mag. The period is consistent with the 2.50 h period obtained by Warner (2011).

12738 Satoshimiki. We observed this asteroid for four nights from 2011 Dec 6 to 2012 Jan 7. We obtained a period *P* = 8.708 ± 0.001 h and an amplitude *A* = 0.25 ± 0.02 mag. During the same observation season, Melton *et al.* (2012) obtained an amplitude of 0.20 mag, and Oey (2012) obtained a period of 8.7081 ± 0.0006 h and an amplitude of 0.20 mag. Our results are consistent with these previously published results.

(23233) 2000 WM72. We observed this asteroid for three nights from 2012 Apr 4-8. We obtained a period *P* = 3.732 ± 0.003 h and amplitude *A* = 0.35 ± 0.02 mag. No previously published results were found.

Acknowledgements

We would like to thank F. Levinson for a generous gift enabling Butler University's membership in the SARA consortium. We would also like to thank the support by the National Natural Science Foundation of China (Grant Nos. 11178025, 11273067 and 10933004), and the Minor Planet Foundation of Purple Mountain Observatory.

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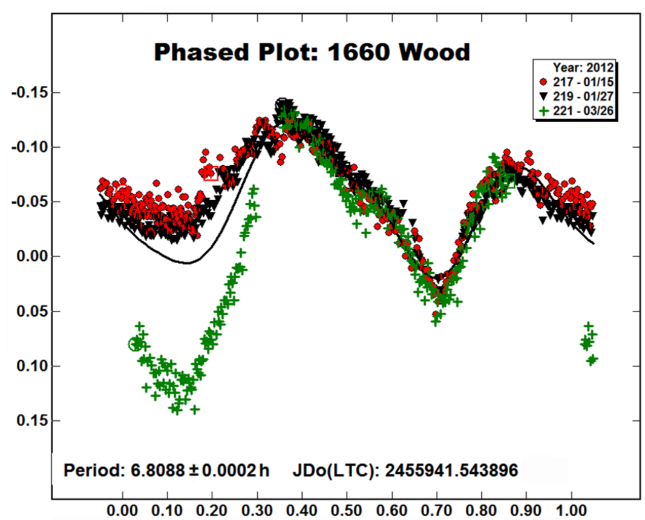

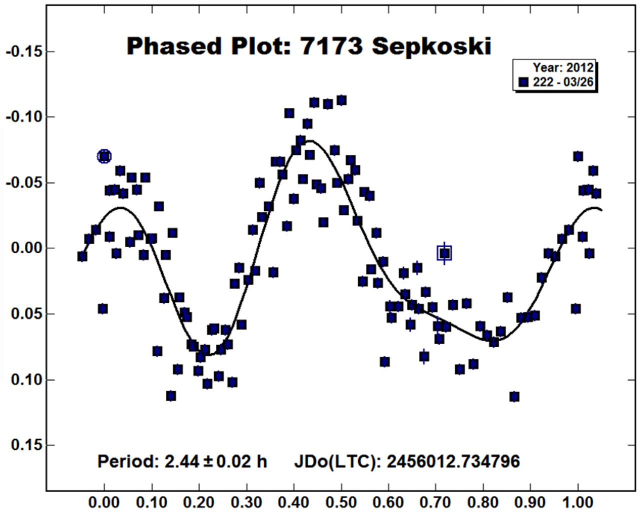

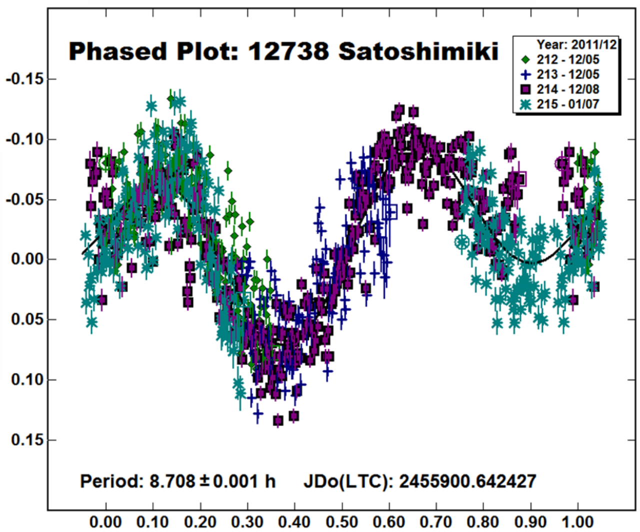

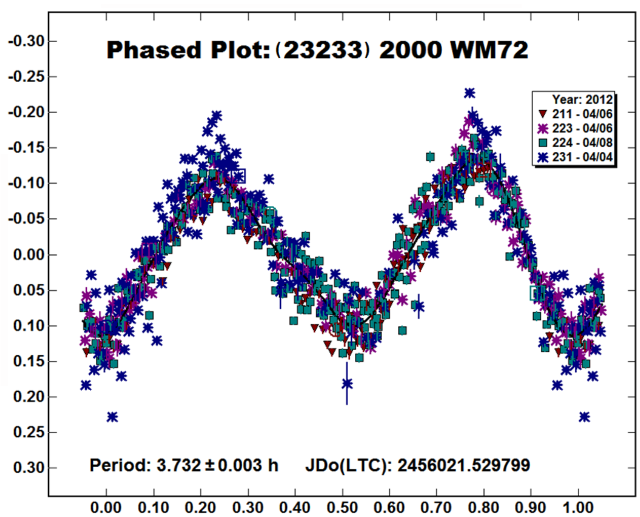

LIGHTCURVE ANALYSIS OF 3948 BOHR AND 4874 BURKE: AN INTERNATIONAL COLABORATION

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An international collaboration provided complete coverage of the 24.884 ± 0.002 h period for 3948 Bohr and a confirmation of a 3.657 ± 0.001 h period for 4874 Burke. The amplitudes were A = 0.89 ± 0.10 mag for 3948 Bohr and A = 0.22 ± 0.07 mag for 4874 Burke.

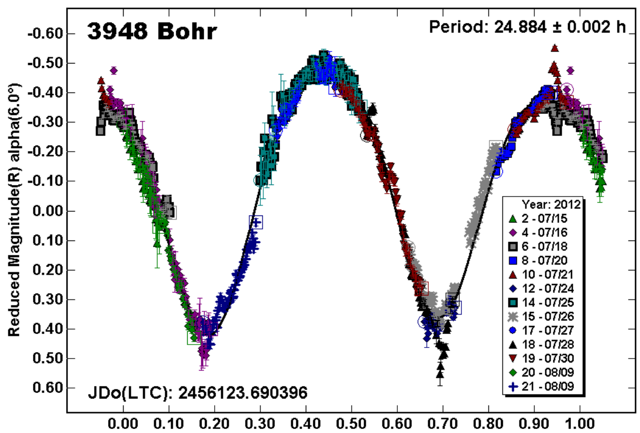
The Etscorn Campus Observatory used two 35.6-cm f/11 Schmidt-Cassegrain telescopes and SBIG STL-1001E CCDs with 1024x1024x24-micron pixels. This gave a plate scale of 1.25 arcseconds/pixel. The exposure time for all images of 3948 Bohr was 180 seconds through a clear filter. The exposure time for all images of 4874 Burke was 300 seconds through a clear filter. For 4874 Burke, the CCD was cooled to –30°C or –35°C, depending on the night-time temperature while the temperature setting was –10°C for 3948 Bohr. The images were dark-subtracted and flat-field corrected using the batch processing routines within *MPO Canopus* (Warner, 2011). The processed images were measured and lightcurves obtained with the same *MPO Canopus* software package.

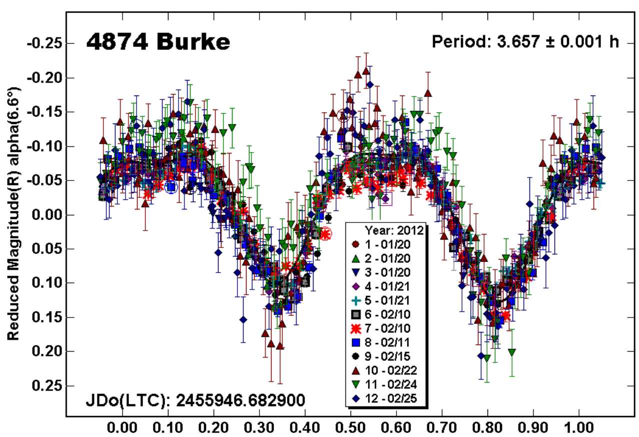
The Bigmuskie Observatory used a 30-cm f/8 Ritchey-Chretien and SBIG ST-9 with 512x512x20-micron pixels resulting in a plate scale of 1.72 arcseconds/pixel. All exposures for both asteroids were obtained through an R AstroDon filter. The exposure times for the 3948 Bohr images were 180 seconds while the exposure times for 4874 Burke were 240 seconds. The CCD was cooled to –10°C for the 3948 Bohr images and –30°C for the 4874 Burke images. Images were corrected with dark and flat fields using the routines in *MPO Canopus* (Warner, 2011). The same software was used to measure the images and produce the lightcurve.

3948 Bohr is a small main-belt asteroid discovered by Poul Jensen in 1985. It is has been known as 1975 TG5, 1975 VH7, 1978 NR1, 1981 JF, and 1985 RF (JPL, 2012). It is named after the Danish Physicist Niels Bohr. It was observed on 12 nights between 2012 Jul 15 and 2012 Aug 9. A total of 800 observations were used in fitting the lightcurve with *MPO Canopus*. The final period has a simple bimodal shape with a period of 24.884 ± 0.002 h and an amplitude of A = 0.89 ± 0.10 mag. In the lightcurve for 3948 Bohr, the data from Bigmuskie Observatory are listed as sessions 19 and 21 and provide the complete coverage of the lightcurve. There is no reference to any known period in the Lightcurve Database (LCDB; Warner *et al.*, 2009)

4874 Burke was discovered by E. F. Helin at Palomar observatory in 1991. It is has been known as 1928 BB, 1970 EC, 1987 EM, and 1991 AW (JPL, 2012). It was observed on 8 nights between 2012 Jan 20 and Feb 25. A total of 755 observations were used in fitting the lightcurve with *MPO Canopus*. The final lightcurve is basically bimodal but has some indication of flattening of the maximums. 4874 Burke was observed by Aymani (2012), who obtained a period of 3.657 ± 0.001 and amplitude A = 0.31 mag. Menzies (2012) obtained a period of 3.656 ± 0.001 and an amplitude of 0.23 ± 0.02 mag.

The 115° longitude difference between the Etscorn Campus Observatory and the Bigmuskie Observatory allowed almost an 8 hour (~0.3) phase shift for 3948 Bohr. This allowed us to cover the nearly 24-hour sidereal period asteroid completely. This type of international collaboration is essential for asteroid with periods near 24 hours. The collaboration continued with the observations of 4874 Burke's 3.657-hour period





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LIGHTCURVES FOR 1394 ALGOA, 3078 HORROCKS, 4724 BROCKEN, AND 6329 HIKONEJYO FROM ETSCORN CAMPUS OBSERVATORY

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Between 2012 March and June, four asteroids were observed at the Etscorn Campus Observatory. Synodic periods and amplitudes were determined for all four: 1394 Algoa, P = 2.768 ± 0.001 h, A = 0.21 ± 0.10 mag; 3078 Horrocks, P = 13.620 ± 0.003 h, A = 0.25 ± 0.10 mag; 4724 Brocken, P = 5.912 ± 0.001 h, A = 0.75 ± 0.10 mag; and 6329 Hikonejyo, P = 6.064 ± 0.001 h, A = 0.23 ± 0.10 mag.

Continuing with the lightcurve program at Etscorn Campus Observatory, we obtained data for four asteroids using our two Celestron 35.6-cm f/11 Schmidt-Cassegrain telescopes and SBIG STL-1001E CCD cameras with 1024x1024x24-micron pixels. This combination gave a plate scale of 1.25 arcseconds/pixel. Images for all asteroids were done through a clear filter. The images were dark subtracted and flat-field corrected using the batch processing routines within *MPO Canopus* version 10.4.1.0 Warner (2012). The processed images were measured and lightcurves obtained with the *MPO Canopus* software package.

1394 Algoa is a main-belt asteroid discovered by Cynl V. Jackson on 1936 Jun 12 at Union Observatory in Johannesburg (JPL, 2012). It has carried designations of 1936 LK, 1929 TT, and 1933 UY1. It has an orbital period of ~ 3.8 years. 1394 Algoa was observed on 11 nights from 2012 May 28 through Jun 26 for a total of 471 images. Exposures were 300 seconds each. The synodic period was determined to be 2.768 ± 0.001 h with an amplitude of 0.21 ± 0.10 mag. The lightcurve has a typical bimodal shape with about 0.05 mag difference in the depths of the minimums. Analysis of observations of 1394 Algoa reported by Hills (2012) found the same period and amplitude.

3078 Horrocks is main-belt asteroid discovered by E. Bowell on 1984 Mar 31 at the Anderson Mesa Station operated by Lowell Observatory (JPL, 2012). It is named after Jeremiah Horrocks, who was the first person to observe a transit of Venus in 1639. It has been known as 1984 FG, 1964 TS1, 1970 SE1, 1973 GS, 1976 YX6, 1978 ET4, and 1982 YQ1. It has an orbital period of ~ 5.59 years. 3078 Horrocks was observed on 9 nights between 2012 Apr 12-30 for a total of 644 images. Exposures were 180 seconds each. The synodic period was determined to be 13.620 ± 0.003 h with an amplitude of 0.25 ± 0.10 mag.

4724 Brocken was discovered by Hoffmeister-Schubart on 1961 Jan 18 at Tautenburg (JPL, 2012). It has been known as 1961 BC, 1961 CE, 1982 HV1, 1985 DO1, and 1986 VG5. It has an orbital period of ~ 3.31 years. 4724 Brocken was observed on 11 nights between 2012 May 27 through Jun 16 for a total of 749 images. Exposures were 180 seconds each. The synodic period was determined to be 5.912 ± 0.001 h with an amplitude of 0.75 ± 0.10

mag. The lightcurve has a typical bimodal shape with both minimums being nearly equal.

6329 Hikonejyo is a main-belt asteroid discovered by A. Sugie at Dynic Astronomical Observatory (JPL, 2012). It has been known as 1992 EU1 and 1982 HC1. It has an orbital period of ~ 3.36 years. 6329 Hikonejyo was observed on 5 nights between 2012 Mar 16-29 for a total of 622 images. Exposures were 180 seconds each. The synodic period was determined to be 6.064 ± 0.001 h with an amplitude of 0.23 ± 0.10 mag. The lightcurve has a typical bimodal shape with the equally deep minimums but one maximum is about 0.05 magnitudes less than the other and appears to have flat top.

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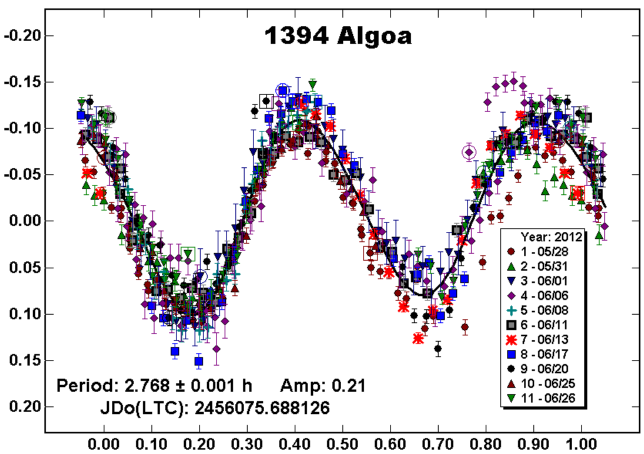

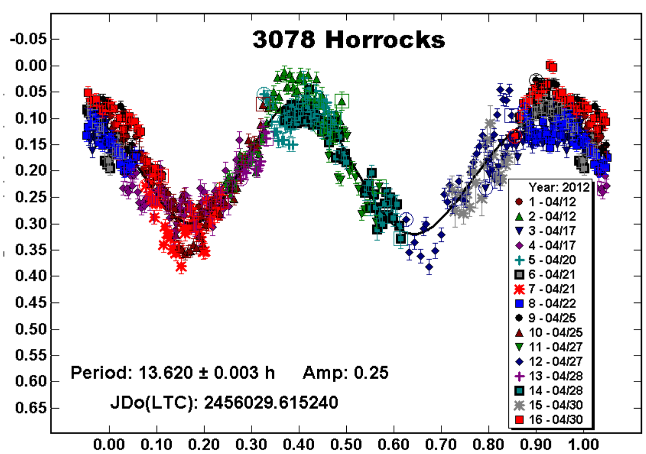

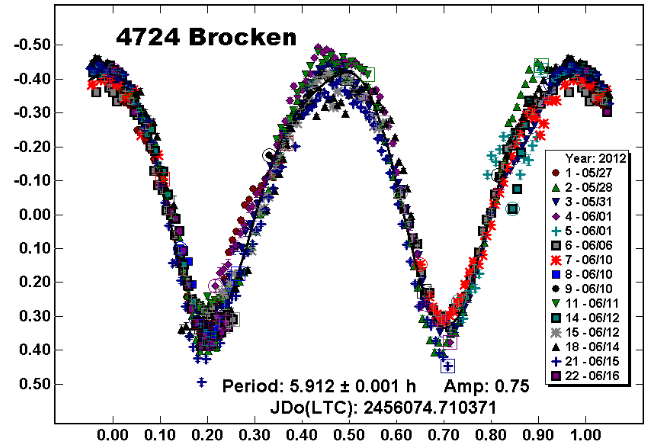

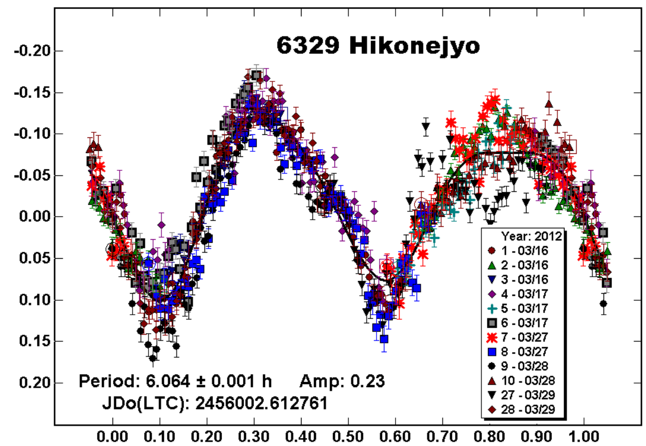

ASTEROID LIGHTCURVE ANALYSIS AT THE OAKLEY OBSERVATORIES: 2012 MAY – JUNE

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Photometric data for 20 asteroids were collected over 12 nights of observing during 2012 May and June at the Oakley Southern Sky Observatories. The asteroids were: 252 Clementina, 481 Emita, 627 Charis, 1108 Demeter, 1121 Natascha, 1315 Bronislawa, 1481 Tubingia, 1844 Susilva, 2602 Moore, 2660 Wasserman, 2826 Ahti, 3159 Prokof'ev, 3306 Byron, 3493 Stepanov, 3795 Nigel, 5256 Farquhar, (6212) 1993 MS1, (19793) 2000 RX42, (24689) 1990 OH1, and (26722) 2001 HK7.

Twenty asteroids were observed from the Oakley Southern Sky Observatory in New South Wales, Australia, on the nights of 2012 May 10, 14-21, June 16, and 19-20. Six of these asteroids were also observed from the Oakley Observatory in Terre Haute, Indiana, on the nights of June 16 and 19. Through analyzing the data, we were able to find lightcurves for ten asteroids. Of the ten lightcurves found, eight were for asteroids that had no previously published period. The period of one of the remaining asteroids agrees with the previously published period within experimental uncertainty while the other is inconsistent with the previously published period.

The asteroids were selected based upon their position in the sky an hour after sunset. Then, asteroids with no previously published period were given higher priority than those asteroids that already have a published period. Finally, asteroids with uncertain periods were given priority in hopes that their previously published period could be improved. Both of the telescopes used were f/8.1 0.5-meter Ritchey-Chretien optical tube assemblies mounted on Paramount ME mounts. The cameras were Santa Barbara Instrument Group STL-1001E CCD cameras with a clear filter. The image scale was 1.2 arcseconds per pixel with varied exposure times between 20 and 210 seconds. Calibration of the images was done using master twilight flats, darks, and bias frames. All calibration frames were created using *CCDSoft,* which was also used to process the images. *MPO Canopus* was used to measure the images.

We have the first reported observations of the period of the following asteroids: 1121 Natascha, 3159 Prokof'ev, 3306 Byron, 3493 Stepanov, 3795 Nigel, (6212) 1993 MS1, (19793) 2000 RX42, (26722) 2001 HK7.

252 Clementina. Our result is consistent with a period of 10.8612 ± 0.0003 h found by Behrend (2009).

1315 Bronislawa. Our result is not within formal uncertainty with the period of 9.565 ± 0.006 h found by Ditteon (2011). However, our data can be fit to the period of 9.565 h found earlier, just with a greater RMS value for the fit.

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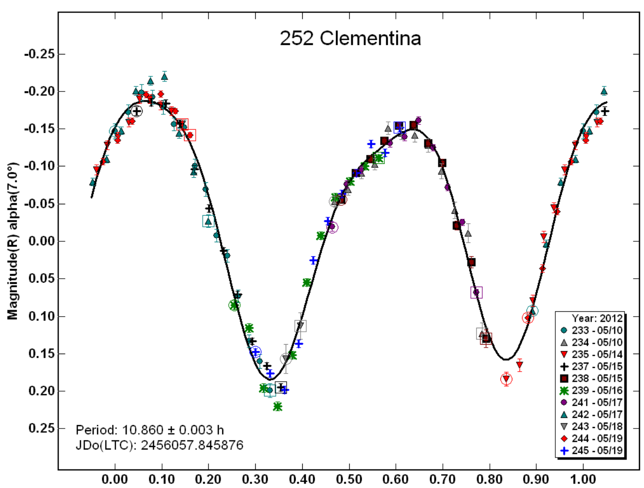
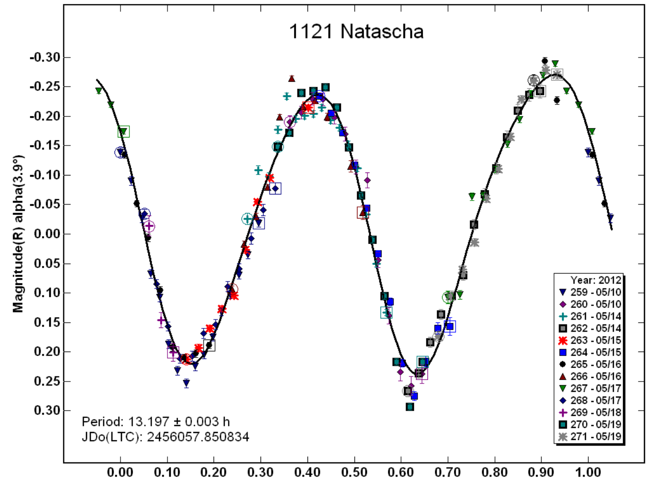
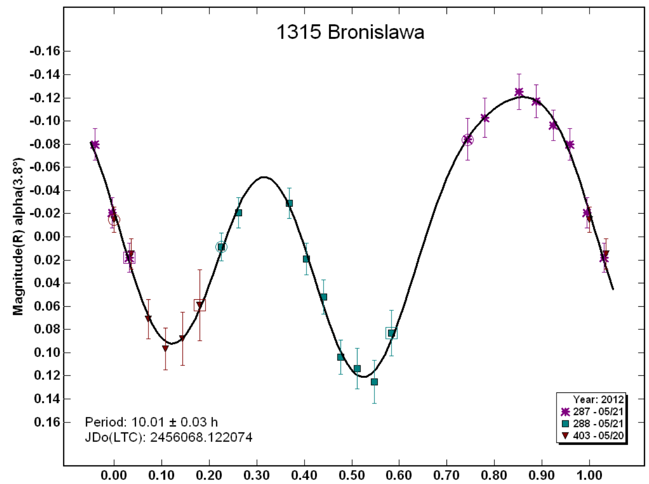
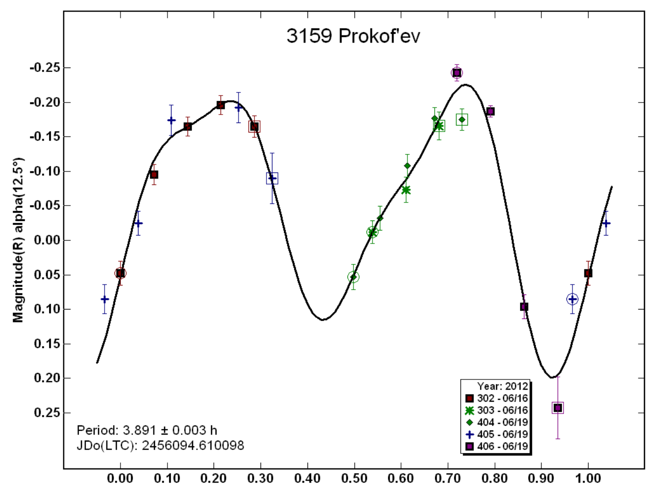


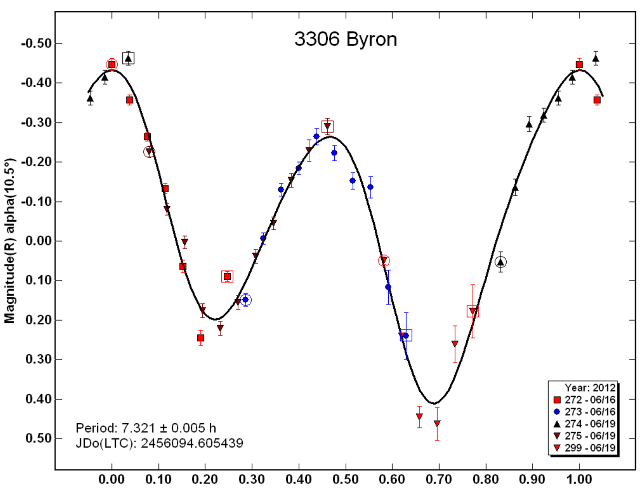


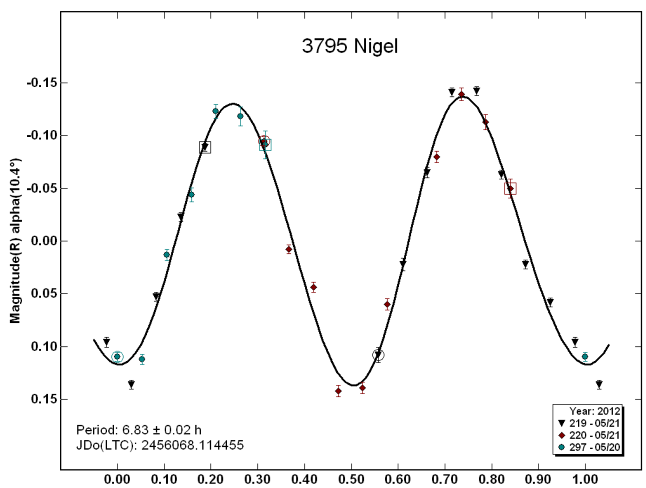


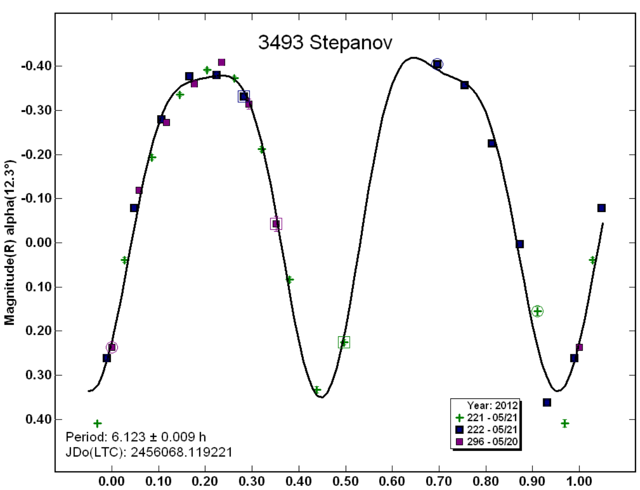


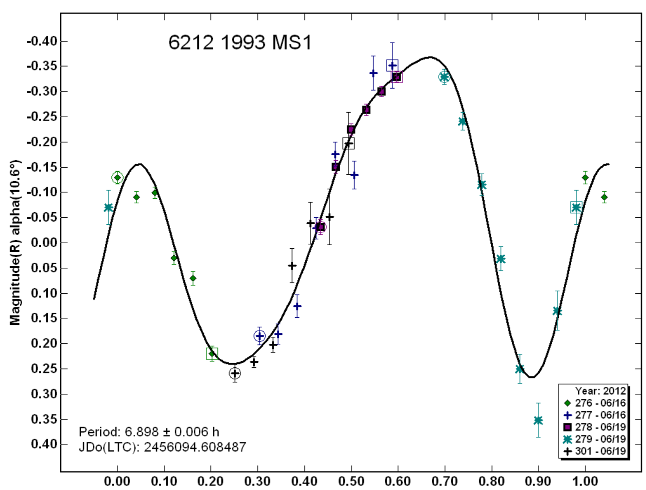
Number	Name	Dates mm/dd 2012	Points	Period (h)	P.E. (h)	Amp (mag)	A.E. (mag)
252	Clementina	5/10, 14-17, 19	118	10.860	0.003	0.37	0.03
481	Emita	5/10, 14-19	28			0.09	0.06
627	Charis	6/16, 19-20	47			0.46	0.07
1108	Demeter	5/10, 14-19	158			0.07	0.03
1121	Natascha	5/10, 14-19	153	13.197	0.003	0.51	0.03
1315	Bronislawa	5/20-21	23	10.01	0.03	0.24	0.02
1481	Tubingia	5/10, 14-19	147			0.41	0.03
1844	Susilva	6/16, 19-20	25			0.47	0.09
2602	Moore	5/20-21	22			0.30	0.04
2660	Wasserman	5/20-21	27			0.07	0.06
2826	Ahti	5/10, 14-19	119			0.08	0.02
3159	Prokof'ev	6/16, 19	22	3.891	0.003	0.42	0.04
3306	Byron	6/16, 19	41	7.321	0.005	0.84	0.05
3493	Stepanov	5/20-21	29	6.123	0.009	0.77	0.04
3795	Nigel	5/20-21	30	6.83	0.02	0.27	0.02
5256	Farquhar	5/10, 14-19	157			0.04	0.03
6212	1993 MS1	6/16, 19	35	6.898	0.006	0.63	0.04
19793	2000 RX42	6/16, 19-20	29	3.102	0.002	0.38	0.04
24689	1990 OH1	5/20-21	31			0.38	0.05
26722	2001 HK7	5/10, 14-19	143	20.252	0.007	0.53	0.01

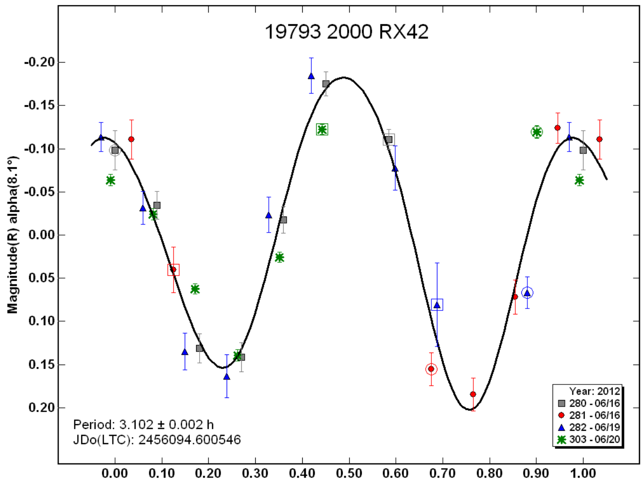
Table I. Observation circumstances and results.

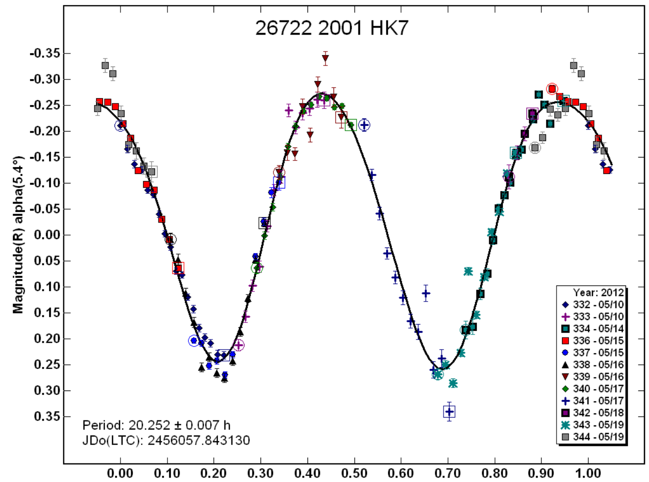












LIGHTCURVE FOR 6376 SCHAMP

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CCD photometric observations of the main-belt asteroid 6376 Schamp were obtained from three observatories in July 2012. A synodic period of 6.613 ± 0.001 h with an amplitude of 0.16 ± 0.02 was found.

6376 Schamp was selected as a target of the Photometric Survey for Asynchronous Binary Asteroids (Pravec 2012). No previous periods are reported in the Lightcurve Database (Warner 2012).

Stephens obtained observations from July 21 to 26 were using a 0.4-m or 0.35-m telescope at the CS3 with a SBIG ST-1001e CCD camera. Pollock obtained the July 29 observations using the 32-inch (0.8-m) telescope at the ASU Dark Sky Observatory with a Apogee Alta 47 CCD camera. The July 30 observations were obtained by Pollock using a 0.41-m Skynet PROMPT telescope at Cerro Tololo Inter-American Observatory with an Apogee Alta U47 CCD camera. The average phase angle over the short observing run was 10.5 degrees.

Period analysis was done using *Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). For purposes of the Binary Asteroid survey, they determined the period to be 6.6093 ± 0.0003 h. We concluded that the 33 rotations combined with the amplitude uncertainty was insufficient to state the period at that level of precision, so report our period as 6.613 ± 0.001 h.

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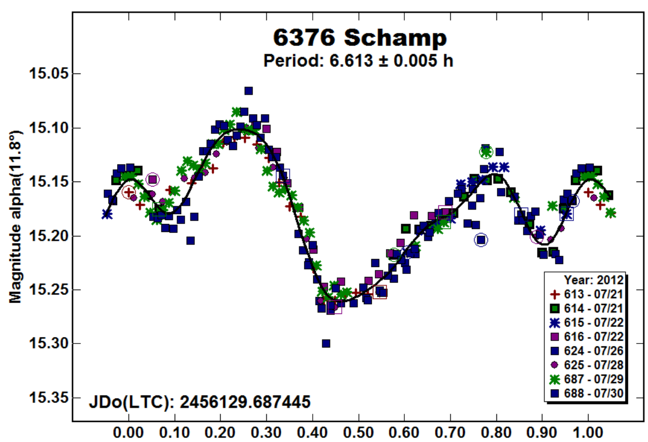

ROTATION PERIOD DETERMINATION FOR 827 WOLFIANA

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For previously unstudied 827 Wolfiana a rotation period of 4.0654 ± 0.0001 hours and amplitude 0.20 ± 0.03 magnitude have been found.

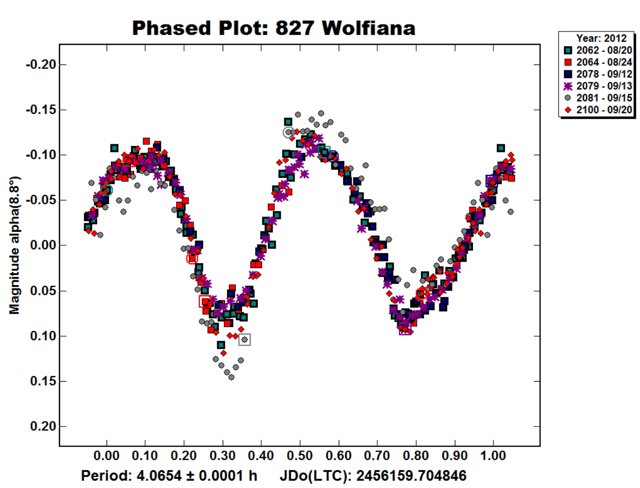
Minor planet 827 Wolfiana was selected for observation because Warner et al. (2012) show no previous photometric observations and because at its 2012 September opposition it was considerably brighter than at any time for the next several years. Observations by Pilcher were made at the Organ Mesa Observatory with a Meade 35 cm LX200 GPS S-C, SBIG STL-1001E CCD, unguided exposures. Martinez used a Celestron CPC 1100 28 cm Schmidt Cassegrain, SBIG ST8XME CCD, clear filter. Both observers used differential photometry only.

MPO Canopus software was used by both observers to measure the images photometrically, share data, adjust instrumental magnitudes up or down to produce the best fit, and prepare the lightcurve. Due to the large number of data points acquired the lightcurve has been binned in sets of three data points with a maximum of five minutes between points.

When data for 6 nights 2012 Aug. 20 - Sept. 20 were combined they produced a very well defined asymmetric bimodal lightcurve with period 4.0654 ± 0.0001 hours, amplitude 0.20 ± 0.03 magnitudes.

References

Warner, B. D., Harris, A. W., and Pravec, P. (2012) “Asteroid Lightcurve Data File, June 24, 2012.” *http://www.minorplanet.info/lightcurvedatabase.html*



MINOR PLANETS AT UNUSUALLY FAVORABLE ELONGATIONS IN 2013

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A list is presented of minor planets which are much brighter than usual at their 2013 apparitions.

The minor planets in the lists which follow will be much brighter at their 2013 apparitions than at their average distances at maximum elongation. Many years may pass before these planets will be again as bright as in 2013. Observers are encouraged to give special attention to those which lie near the limit of their equipment.

These lists have been prepared by an examination of the maximum elongation circumstances of minor planets computed by the author for all years through 2060 with a full perturbation program written by Dr. John Reed, and to whom he expresses his thanks. Elements are from EMP 1992, except that for all planets for which new or improved elements have been published subsequently in the Minor Planet Ciculars or in electronic form, the newer elements have been used. Planetary positions are from the JPL DE-200 ephemeris, courtesy of Dr. E. Myles Standish.

Any planets whose brightest magnitudes near the time of maximum elongation vary by at least 2.0 in this interval and in 2013 will be within 0.3 of the brightest occuring, or vary by at least 3.0 and in 2013 will be within 0.5 of the brightest occuring; and which are visual magnitude 14.5 or brighter, are included. For planets brighter than visual magnitude 13.5, which are within the range of a large number of observers, these standards have been relaxed somewhat to include a larger number of planets. Magnitudes have been computed from the updated magnitude parameters published in MPC28104-28116, on 1996 Nov. 25, or more recently in the Minor Planet Circulars.

Oppositions may be in right ascension or in celestial longitude. Here we use still a third representation, maximum elongation from the Sun, instead of opposition. Though unconventional, it has the advantage that many close approaches do not involve actual opposition to the Sun near the time of minimum distance and greatest brightness and are missed by an opposition-based program. Other data are also provided according to the following tabular listings: Minor planet number, date of maximum elongation from the Sun in format yyyy/mm/dd, maximum elongation in degrees, right ascension on date of maximum elongation, declination on date of maximum elongation, both in J2000 coordinates, date of brightest magnitude in format yyyy/mm/dd, brightest magnitude, date of minimum distance in format yyyy/mm/dd, and minimum distance in AU.

Users should note that when the maximum elongation is about 177° or greater, the brightest magnitude is sharply peaked due to enhanced brightening near zero phase angle. Even as near as 10 days before or after minimum magnitude the magnitude is generally about 0.4 greater. This effect takes place in greater time interval for smaller maximum elongations. There is some interest in very small minimum phase angles. For maximum elongations E near 180° at Earth distance Δ , an approximate formula for the minimum phase angle ϕ is $\phi = (180° – E)/(\Delta+1)$.

The year 2013 will be a banner year for close approaches. Ten numbered asteroids can be predicted become brighter than magnitude 14.5 during close approaches. These are provided in a separate Table III at the end of this paper.

Table I. Numerical Sequence of Favorable Elongations

Planet	Max Elon D	Max E	RA	Dec	Br Mag D	Br Mag	Min Dist D	Min Dist
9	2013/01/01	174.4°	6h51m	+28°	2013/01/01	8.5	2012/12/30	1.136
14	2013/03/19	163.2°	12h25m	+15°	2013/03/20	9.0	2013/03/21	1.185
25	2013/05/13	164.6°	15h48m	- 4°	2013/05/16	10.0	2013/05/25	1.042
47	2013/07/26	172.8°	20h32m	-26°	2013/07/27	11.0	2013/07/27	1.494
76	2013/11/23	178.1°	3h56m	+18°	2013/11/23	11.8	2013/11/25	1.947
86	2013/10/10	172.4°	1h13m	- 0°	2013/10/10	11.7	2013/10/11	1.489
89	2013/09/23	156.4°	23h29m	+22°	2013/09/22	9.1	2013/09/21	1.128
93	2013/08/07	168.9°	21h24m	-26°	2013/08/07	10.8	2013/08/03	1.417
128	2013/10/05	170.4°	0h58m	- 4°	2013/10/05	10.5	2013/10/04	1.418
137	2013/09/26	172.8°	0h 0m	+ 7°	2013/09/26	11.5	2013/09/19	1.626
156	2013/05/09	175.6°	14h57m	-21°	2013/05/09	10.7	2013/05/08	1.106
157	2013/01/14	161.6°	8h 8m	+38°	2013/01/14	13.0	2013/01/13	1.122
166	2013/11/19	159.0°	3h52m	- 1°	2013/11/17	12.6	2013/11/14	1.196
176	2013/10/05	173.8°	0h30m	+ 9°	2013/10/05	11.4	2013/10/05	1.679
204	2013/04/13	179.5°	13h25m	- 9°	2013/04/13	11.5	2013/04/20	1.358
211	2013/01/01	178.1°	6h48m	+21°	2013/01/01	11.1	2012/12/30	1.595
216	2013/11/15	172.1°	3h35m	+11°	2013/11/15	9.5	2013/11/11	1.136
225	2013/06/11	149.5°	17h36m	+ 7°	2013/06/16	12.6	2013/06/19	1.677
324	2013/09/12	170.3°	23h12m	+ 5°	2013/09/13	8.2	2013/09/17	0.810
330	2013/08/28	175.9°	22h33m	-13°	2013/08/28	14.5	2013/09/06	1.044
350	2013/12/07	168.6°	4h56m	+11°	2013/12/07	11.9	2013/12/06	1.646
351	2013/02/11	169.1°	9h56m	+24°	2013/02/10	11.9	2013/02/10	1.375
358	2013/10/25	176.2°	2h 5m	+ 8°	2013/10/25	12.2	2013/10/27	1.503
378	2013/10/18	174.4°	1h22m	+14°	2013/10/18	12.8	2013/10/17	1.431
387	2013/07/12	168.0°	19h12m	-10°	2013/07/12	9.7	2013/07/12	1.086
394	2013/09/09	168.5°	23h30m	-15°	2013/09/09	12.0	2013/09/06	1.143
417	2013/04/12	179.4°	13h24m	- 8°	2013/04/12	12.1	2013/04/12	1.429
418	2013/09/21	168.6°	23h36m	+ 9°	2013/09/21	12.6	2013/09/22	1.305
435	2013/09/13	178.1°	23h28m	- 5°	2013/09/13	12.1	2013/09/13	1.068
445	2013/11/06	148.5°	1h46m	+44°	2013/11/03	13.3	2013/11/01	1.738
455	2013/07/12	166.9°	19h40m	-34°	2013/07/14	11.1	2013/07/23	1.082
470	2013/05/10	168.8°	15h21m	- 6°	2013/05/10	12.6	2013/05/10	1.181
479	2013/09/27	168.2°	0h37m	- 8°	2013/09/28	12.2	2013/10/02	1.236
488	2013/01/16	170.2°	8h 4m	+30°	2013/01/17	11.6	2013/01/20	1.766
505	2013/12/04	173.6°	4h42m	+15°	2013/12/04	10.6	2013/12/03	1.042
510	2013/08/12	163.9°	21h 5m	+ 0°	2013/08/11	12.2	2013/08/07	1.146
511	2013/12/01	163.7°	4h37m	+ 5°	2013/12/02	9.8	2013/12/03	1.629
539	2013/09/17	167.6°	23h22m	+ 9°	2013/09/18	12.2	2013/09/19	1.187
542	2013/09/17	172.4°	23h54m	- 8°	2013/09/17	12.6	2013/09/17	1.513
543	2013/01/12	179.3°	7h38m	+22°	2013/01/12	13.0	2013/01/08	1.831
560	2013/12/13	174.0°	5h24m	+17°	2013/12/13	13.4	2013/12/16	1.361
572	2013/10/27	172.9°	2h19m	+ 6°	2013/10/27	12.9	2013/10/25	1.037
576	2013/07/12	177.0°	19h28m	-24°	2013/07/12	12.4	2013/07/16	1.461
599	2013/09/26	156.9°	0h35m	-21°	2013/09/23	11.0	2013/09/19	1.030
686	2013/06/30	161.3°	18h42m	- 4°	2013/07/03	12.0	2013/07/10	1.052
709	2013/09/14	167.4°	23h12m	+ 8°	2013/09/14	12.5	2013/09/12	1.600
722	2013/07/20	168.2°	20h 8m	-32°	2013/07/20	13.6	2013/07/20	0.851
736	2013/09/11	174.8°	23h27m	- 9°	2013/09/11	12.9	2013/09/08	0.839
758	2013/01/09	179.5°	7h23m	+22°	2013/01/09	11.8	2013/01/05	1.841
776	2013/12/22	174.0°	6h 7m	+29°	2013/12/22	11.1	2013/12/17	1.685
784	2013/05/20	164.7°	15h38m	-35°	2013/05/21	12.0	2013/05/23	1.368
788	2013/03/05	174.9°	10h55m	+ 1°	2013/03/05	12.2	2013/03/10	1.899
839	2013/09/01	179.7°	22h41m	- 7°	2013/09/01	12.4	2013/08/29	1.225
899	2013/12/07	179.0°	4h54m	+21°	2013/12/06	13.1	2013/11/30	1.519
937	2013/05/29	179.4°	16h25m	-21°	2013/05/29	13.3	2013/06/09	0.935
941	2013/11/05	178.1°	2h45m	+14°	2013/11/05	14.0	2013/11/02	1.268
955	2013/09/13	179.7°	23h25m	- 4°	2013/09/13	13.3	2013/08/31	1.199
989	2013/10/20	162.3°	1h 4m	+25°	2013/10/21	14.1	2013/10/24	1.058
994	2013/09/30	177.4°	0h24m	+ 5°	2013/09/30	12.7	2013/09/27	1.256
1011	2013/01/27	178.5°	8h36m	+17°	2013/01/27	12.6	2013/01/27	0.569
1035	2013/09/24	179.7°	0h 6m	+ 0°	2013/09/24	13.5	2013/09/19	1.606
1040	2013/01/12	173.9°	7h35m	+15°	2013/01/12	13.7	2013/01/09	1.603
1058	2013/08/05	171.5°	20h52m	- 8°	2013/08/05	13.1	2013/08/05	0.775
1065	2013/08/06	173.7°	21h 9m	-22°	2013/08/06	13.7	2013/08/08	0.652
1074	2013/10/31	179.7°	2h23m	+14°	2013/10/31	13.2	2013/11/02	1.637
1099	2013/11/06	172.6°	2h39m	+23°	2013/11/05	13.4	2013/10/30	1.437
1125	2013/11/22	177.0°	3h52m	+17°	2013/11/22	14.5	2013/11/27	1.611
1133	2013/08/28	168.0°	22h48m	-20°	2013/08/29	13.6	2013/09/02	0.812
1241	2013/08/15	179.3°	21h41m	-13°	2013/08/15	13.2	2013/08/13	1.906
1270	2013/09/10	167.1°	23h36m	-16°	2013/09/10	13.7	2013/09/10	0.779
1277	2013/05/23	178.9°	16h 0m	-21°	2013/05/23	13.3	2013/06/01	1.194
1326	2013/12/01	163.7°	4h32m	+ 5°	2013/11/29	13.6	2013/11/24	1.227
1354	2013/05/23	174.5°	15h54m	-25°	2013/05/23	14.5	2013/05/28	1.527
1358	2013/08/20	176.6°	22h 2m	-15°	2013/08/20	14.1	2013/08/16	1.067
1387	2013/08/30	170.8°	22h19m	- 0°	2013/08/30	14.1	2013/08/27	0.786
1496	2013/07/09	179.2°	19h13m	-23°	2013/07/09	13.9	2013/07/10	0.833
1510	2013/02/05	174.5°	9h22m	+21°	2013/02/05	13.8	2013/02/06	1.295
1539	2013/12/04	177.4°	4h43m	+19°	2013/12/04	14.0	2013/11/29	1.666
1590	2013/07/28	170.9°	20h23m	-10°	2013/07/28	13.3	2013/07/24	0.894
1610	2013/09/29	179.2°	0h24m	+ 3°	2013/09/29	13.9	2013/09/30	0.767
1626	2013/12/08	150.8°	3h50m	+48°	2013/12/08	12.0	2013/12/07	0.787
1627	2013/10/15	156.4°	1h48m	-14°	2013/07/07	12.5	2013/07/06	0.322
1638	2013/08/23	179.5°	22h 7m	-11°	2013/08/23	14.0	2013/08/16	1.310
1653	2013/10/07	171.4°	0h39m	+13°	2013/10/08	12.6	2013/10/11	0.798
1668	2013/08/27	179.0°	22h23m	- 8°	2013/08/27	14.5	2013/08/29	1.214
1683	2013/08/21	179.2°	22h 2m	-11°	2013/08/21	13.9	2013/08/18	1.247
1709	2013/08/09	175.3°	21h11m	-11°	2013/08/09	14.2	2013/08/13	0.890
1719	2013/10/08	158.3°	0h25m	+26°	2013/10/08	13.8	2013/10/07	1.113
1727	2013/01/17	162.1°	7h26m	+ 4°	2013/01/17	13.8	2013/01/15	0.719
1761	2013/01/03	178.1°	6h59m	+24°	2013/01/03	14.4	2013/01/07	1.487
1792	2013/12/11	178.1°	5h13m	+24°	2013/12/11	14.1	2013/12/03	1.134
1874	2013/08/24	178.8°	22h11m	- 9°	2013/08/24	13.4	2013/08/28	1.271
1886	2013/07/11	166.8°	19h41m	-34°	2013/07/12	14.5	2013/07/12	1.212
1902	2013/08/24	161.6°	22h42m	-28°	2013/08/24	14.0	2013/08/23	2.109
1909	2013/05/20	179.0°	15h52m	-19°	2013/05/20	14.1	2013/05/20	0.866
1994	2013/06/18	173.2°	17h48m	-16°	2013/06/18	14.4	2013/06/26	1.346
2036	2013/07/18	173.1°	19h55m	-27°	2013/07/18	13.9	2013/07/17	0.814
2121	2013/07/22	175.6°	20h 3m	-15°	2013/07/22	13.3	2013/07/23	0.780
2212	2013/10/26	109.8°	21h54m	-22°	2013/10/05	14.1	2013/09/28	0.300
2213	2013/07/29	179.5°	20h36m	-18°	2013/07/29	14.5	2013/08/07	0.764
2231	2013/09/12	178.0°	23h18m	- 2°	2013/09/12	14.3	2013/09/14	1.063
2409	2013/09/08	176.7°	23h14m	- 8°	2013/09/08	14.3	2013/09/07	0.829
2505	2013/06/20	178.2°	17h53m	-25°	2013/06/20	14.5	2013/06/20	1.582
2543	2013/07/09	155.7°	19h38m	-46°	2013/07/13	14.1	2013/07/17	1.340
2546	2013/04/13	161.8°	13h 1m	-26°	2013/04/13	14.5	2013/04/12	1.137
2568	2013/06/09	177.1°	17h10m	-20°	2013/06/09	14.1	2013/06/14	0.796
2672	2013/07/10	170.3°	19h 9m	-12°	2013/07/10	14.2	2013/07/09	1.213
2728	2013/06/07	175.9°	17h 3m	-18°	2013/06/07	14.5	2013/06/13	1.104
2771	2013/10/03	171.8°	0h19m	+10°	2013/10/02	14.4	2013/09/25	1.186
2829	2013/07/27	171.3°	20h30m	-27°	2013/07/27	13.5	2013/07/26	1.489
2830	2013/04/25	164.1°	14h16m	+ 2°	2013/04/24	14.5	2013/04/23	0.926
2831	2013/09/18	170.4°	23h58m	-10°	2013/09/18	13.8	2013/09/17	0.788
2880	2013/05/08	178.3°	14h59m	-18°	2013/05/08	14.1	2013/05/16	0.951
3106	2013/12/12	163.3°	5h17m	+ 6°	2013/12/11	14.1	2013/12/08	1.489
3169	2013/12/27	178.9°	6h22m	+22°	2013/12/27	13.6	2013/12/28	0.800
3224	2013/05/31	177.1°	16h36m	-19°	2013/05/31	14.1	2013/05/30	1.319
3267	2013/01/14	175.7°	7h53m	+25°	2013/01/13	14.3	2013/01/04	0.836
3284	2013/10/02	166.5°	0h53m	- 8°	2013/09/29	14.2	2013/09/18	0.792
3300	2013/09/01	157.0°	23h15m	-29°	2013/08/30	14.2	2013/08/26	1.682
3444	2013/12/13	166.8°	5h15m	+36°	2013/12/12	14.1	2013/12/09	0.920
3581	2013/06/26	121.3°	19h33m	+32°	2013/08/14	14.4	2013/08/14	0.915
3632	2013/11/04	175.4°	2h44m	+11°	2013/11/04	14.4	2013/11/12	0.999
3702	2013/11/23	154.8°	4h 6m	- 4°	2013/11/19	14.3	2013/11/14	1.172
3737	2013/11/26	137.1°	1h34m	+51°	2013/11/07	14.2	2013/10/28	0.645
3738	2013/05/20	177.6°	15h47m	-22°	2013/05/20	13.9	2013/05/25	0.863
3739	2013/07/18	179.4°	19h49m	-21°	2013/07/18	14.5	2013/07/16	0.858
3744	2013/12/15	175.6°	5h34m	+18°	2013/12/15	14.4	2013/12/09	0.968
3752	2013/02/15	127.0°	13h34m	+29°	2013/02/13	13.3	2013/02/12	0.148
3768	2013/08/25	178.1°	22h20m	-12°	2013/08/25	14.4	2013/08/29	1.517
3855	2013/09/16	165.5°	0h 2m	-15°	2013/09/15	14.4	2013/09/12	0.787
3935	2013/01/03	175.0°	6h56m	+27°	2013/01/02	14.3	2012/12/26	1.145
4511	2013/09/16	172.7°	23h38m	- 9°	2013/09/15	13.8	2013/09/06	0.914
4729	2013/09/01	175.1°	22h33m	- 3°	2013/09/01	14.4	2013/09/06	0.893
4905	2013/10/17	177.5°	1h35m	+ 7°	2013/10/17	14.3	2013/10/15	1.174
4925	2013/11/29	179.1°	4h21m	+20°	2013/11/29	14.4	2013/11/22	1.445
5118	2013/07/25	161.6°	20h 6m	- 1°	2013/07/25	14.3	2013/07/26	1.061
5153	2013/01/21	168.0°	8h30m	+31°	2013/01/21	14.3	2013/01/22	1.232
5247	2013/05/06	175.3°	15h 4m	-12°	2013/05/06	14.2	2013/05/10	0.981
5452	2013/05/09	166.4°	14h46m	-30°	2013/05/11	14.3	2013/05/16	0.753
5468	2013/04/07	160.8°	13h37m	+10°	2013/04/08	14.5	2013/04/09	1.266
5622	2013/08/02	172.3°	20h41m	-10°	2013/08/02	14.1	2013/08/03	1.330
5647	2013/12/16	156.3°	6h 5m	+ 0°	2013/12/18	13.8	2013/12/20	0.846
5764	2013/06/24	169.0°	18h11m	-12°	2013/06/23	14.5	2013/06/20	0.802
5847	2013/08/22	168.8°	21h55m	- 0°	2013/08/25	14.4	2013/09/02	0.906
5851	2013/09/10	178.5°	23h17m	- 6°	2013/09/10	14.5	2013/09/03	1.274
5913	2013/09/04	172.8°	22h43m	- 0°	2013/09/04	14.2	2013/09/04	1.114
6063	2013/10/25	147.7°	4h 4m	+ 2°	2013/11/08	12.3	2013/11/11	0.079
6246	2013/11/24	169.3°	4h 3m	+31°	2013/11/25	14.3	2013/11/29	0.808
6406	2013/09/06	174.6°	23h 8m	-11°	2013/09/06	13.9	2013/09/06	0.869
7262	2013/08/05	174.8°	21h10m	-21°	2013/08/04	13.6	2013/07/29	0.686
7536	2013/07/26	179.5°	20h25m	-19°	2013/07/26	14.5	2013/07/25	1.396
7731	2013/12/06	174.1°	4h51m	+28°	2013/12/06	14.4	2013/12/02	1.000
7888	2013/05/14	115.6°	14h12m	+43°	2013/03/28	14.4	2013/03/20	0.126
8400	2013/08/06	176.6°	21h12m	-19°	2013/08/07	14.4	2013/08/13	1.301
12832	2013/10/03	179.9°	0h37m	+ 4°	2013/10/03	14.4	2013/10/03	0.776
14309	2013/10/03	175.8°	0h44m	+ 0°	2013/10/01	14.5	2013/09/05	0.613
14339	2013/07/13	177.4°	19h27m	-19°	2013/07/13	13.9	2013/07/13	1.126
17188	2013/06/24	153.8°	19h12m	- 1°	2013/06/16	13.7	2013/06/12	0.101
24367	2013/08/16	178.5°	21h44m	-15°	2013/08/15	14.5	2013/08/11	0.825
26858	2013/10/28	167.7°	2h39m	+ 3°	2013/10/30	13.8	2013/11/09	0.716
52762	2013/01/16	127.2°	11h23m	+ 6°	2013/01/27	13.6	2013/01/31	0.207
105158	2013/08/20	166.2°	21h59m	+ 1°	2013/08/12	13.8	2013/07/26	0.439
137126	2013/09/09	148.3°	21h13m	-18°	2013/08/26	14.4	2013/08/23	0.064
138095	2013/11/09	110.9°	23h44m	-34°	2013/11/10	13.6	2013/11/10	0.126
163364	2013/06/09	159.1°	15h39m	-22°	2013/05/27	13.9	2013/05/23	0.039

Table II. Temporal Sequence of Favorable Elongations

Planet	Max Elon D	Max E	RA	Dec	Br Mag D	Br Mag	Min Dist D	Min Dist
9	2013/01/01	174.4°	6h51m	+28°	2013/01/01	8.5	2012/12/30	1.136
211	2013/01/01	178.1°	6h48m	+21°	2013/01/01	11.1	2012/12/30	1.595
1761	2013/01/03	178.1°	6h59m	+24°	2013/01/03	14.4	2013/01/07	1.487
3935	2013/01/03	175.0°	6h56m	+27°	2013/01/02	14.3	2012/12/26	1.145
758	2013/01/09	179.5°	7h23m	+22°	2013/01/09	11.8	2013/01/05	1.841
543	2013/01/12	179.3°	7h38m	+22°	2013/01/12	13.0	2013/01/08	1.831
1040	2013/01/12	173.9°	7h35m	+15°	2013/01/12	13.7	2013/01/09	1.603
157	2013/01/14	161.6°	8h 8m	+38°	2013/01/14	13.0	2013/01/13	1.122
3267	2013/01/14	175.7°	7h53m	+25°	2013/01/13	14.3	2013/01/04	0.836
488	2013/01/16	170.2°	8h 4m	+30°	2013/01/17	11.6	2013/01/20	1.766
52762	2013/01/16	127.2°	11h23m	+ 6°	2013/01/27	13.6	2013/01/31	0.207
1727	2013/01/17	162.1°	7h26m	+ 4°	2013/01/17	13.8	2013/01/15	0.719
5153	2013/01/21	168.0°	8h30m	+31°	2013/01/21	14.3	2013/01/22	1.232
1011	2013/01/27	178.5°	8h36m	+17°	2013/01/27	12.6	2013/01/27	0.569
1510	2013/02/05	174.5°	9h22m	+21°	2013/02/05	13.8	2013/02/06	1.295
351	2013/02/11	169.1°	9h56m	+24°	2013/02/10	11.9	2013/02/10	1.375
3752	2013/02/15	127.0°	13h34m	+29°	2013/02/13	13.3	2013/02/12	0.148
788	2013/03/05	174.9°	10h55m	+ 1°	2013/03/05	12.2	2013/03/10	1.899
14	2013/03/19	163.2°	12h25m	+15°	2013/03/20	9.0	2013/03/21	1.185
5468	2013/04/07	160.8°	13h37m	+10°	2013/04/08	14.5	2013/04/09	1.266
417	2013/04/12	179.4°	13h24m	- 8°	2013/04/12	12.1	2013/04/12	1.429
204	2013/04/13	179.5°	13h25m	- 9°	2013/04/13	11.5	2013/04/20	1.358
2546	2013/04/13	161.8°	13h 1m	-26°	2013/04/13	14.5	2013/04/12	1.137
2830	2013/04/25	164.1°	14h16m	+ 2°	2013/04/24	14.5	2013/04/23	0.926
5247	2013/05/06	175.3°	15h 4m	-12°	2013/05/06	14.2	2013/05/10	0.981
2880	2013/05/08	178.3°	14h59m	-18°	2013/05/08	14.1	2013/05/16	0.951
156	2013/05/09	175.6°	14h57m	-21°	2013/05/09	10.7	2013/05/08	1.106
5452	2013/05/09	166.4°	14h46m	-30°	2013/05/11	14.3	2013/05/16	0.753
470	2013/05/10	168.8°	15h21m	- 6°	2013/05/10	12.6	2013/05/10	1.181
25	2013/05/13	164.6°	15h48m	- 4°	2013/05/16	10.0	2013/05/25	1.042
7888	2013/05/14	115.6°	14h12m	+43°	2013/03/28	14.4	2013/03/20	0.126
784	2013/05/20	164.7°	15h38m	-35°	2013/05/21	12.0	2013/05/23	1.368
1909	2013/05/20	179.0°	15h52m	-19°	2013/05/20	14.1	2013/05/20	0.866
3738	2013/05/20	177.6°	15h47m	-22°	2013/05/20	13.9	2013/05/25	0.863
1277	2013/05/23	178.9°	16h 0m	-21°	2013/05/23	13.3	2013/06/01	1.194
1354	2013/05/23	174.5°	15h54m	-25°	2013/05/23	14.5	2013/05/28	1.527
937	2013/05/29	179.4°	16h25m	-21°	2013/05/29	13.3	2013/06/09	0.935
3224	2013/05/31	177.1°	16h36m	-19°	2013/05/31	14.1	2013/05/30	1.319
2728	2013/06/07	175.9°	17h 3m	-18°	2013/06/07	14.5	2013/06/13	1.104
2568	2013/06/09	177.1°	17h10m	-20°	2013/06/09	14.1	2013/06/14	0.796
163364	2013/06/09	159.1°	15h39m	-22°	2013/05/27	13.9	2013/05/23	0.039
225	2013/06/11	149.5°	17h36m	+ 7°	2013/06/16	12.6	2013/06/19	1.677
1994	2013/06/18	173.2°	17h48m	-16°	2013/06/18	14.4	2013/06/26	1.346
2505	2013/06/20	178.2°	17h53m	-25°	2013/06/20	14.5	2013/06/20	1.582
5764	2013/06/24	169.0°	18h11m	-12°	2013/06/23	14.5	2013/06/20	0.802
17188	2013/06/24	153.8°	19h12m	- 1°	2013/06/16	13.7	2013/06/12	0.101
3581	2013/06/26	121.3°	19h33m	+32°	2013/08/14	14.4	2013/08/14	0.915
686	2013/06/30	161.3°	18h42m	- 4°	2013/07/03	12.0	2013/07/10	1.052
1496	2013/07/09	179.2°	19h13m	-23°	2013/07/09	13.9	2013/07/10	0.833
2543	2013/07/09	155.7°	19h38m	-46°	2013/07/13	14.1	2013/07/17	1.340
2672	2013/07/10	170.3°	19h 9m	-12°	2013/07/10	14.2	2013/07/09	1.213
1886	2013/07/11	166.8°	19h41m	-34°	2013/07/12	14.5	2013/07/12	1.212
387	2013/07/12	168.0°	19h12m	-10°	2013/07/12	9.7	2013/07/12	1.086
455	2013/07/12	166.9°	19h40m	-34°	2013/07/14	11.1	2013/07/23	1.082
576	2013/07/12	177.0°	19h28m	-24°	2013/07/12	12.4	2013/07/16	1.461
14339	2013/07/13	177.4°	19h27m	-19°	2013/07/13	13.9	2013/07/13	1.126
2036	2013/07/18	173.1°	19h55m	-27°	2013/07/18	13.9	2013/07/17	0.814
3739	2013/07/18	179.4°	19h49m	-21°	2013/07/18	14.5	2013/07/16	0.858
722	2013/07/20	168.2°	20h 8m	-32°	2013/07/20	13.6	2013/07/20	0.851
2121	2013/07/22	175.6°	20h 3m	-15°	2013/07/22	13.3	2013/07/23	0.780
5118	2013/07/25	161.6°	20h 6m	- 1°	2013/07/25	14.3	2013/07/26	1.061
47	2013/07/26	172.8°	20h32m	-26°	2013/07/27	11.0	2013/07/27	1.494
7536	2013/07/26	179.5°	20h25m	-19°	2013/07/26	14.5	2013/07/25	1.396
2829	2013/07/27	171.3°	20h30m	-27°	2013/07/27	13.5	2013/07/26	1.489
1590	2013/07/28	170.9°	20h23m	-10°	2013/07/28	13.3	2013/07/24	0.894
2213	2013/07/29	179.5°	20h36m	-18°	2013/07/29	14.5	2013/08/07	0.764
5622	2013/08/02	172.3°	20h41m	-10°	2013/08/02	14.1	2013/08/03	1.330
1058	2013/08/05	171.5°	20h52m	- 8°	2013/08/05	13.1	2013/08/05	0.775
7262	2013/08/05	174.8°	21h10m	-21°	2013/08/04	13.6	2013/07/29	0.686
1065	2013/08/06	173.7°	21h 9m	-22°	2013/08/06	13.7	2013/08/08	0.652
8400	2013/08/06	176.6°	21h12m	-19°	2013/08/07	14.4	2013/08/13	1.301
93	2013/08/07	168.9°	21h24m	-26°	2013/08/07	10.8	2013/08/03	1.417
1709	2013/08/09	175.3°	21h11m	-11°	2013/08/09	14.2	2013/08/13	0.890
510	2013/08/12	163.9°	21h 5m	+ 0°	2013/08/11	12.2	2013/08/07	1.146
1241	2013/08/15	179.3°	21h41m	-13°	2013/08/15	13.2	2013/08/13	1.906
24367	2013/08/16	178.5°	21h44m	-15°	2013/08/15	14.5	2013/08/11	0.825
1358	2013/08/20	176.6°	22h 2m	-15°	2013/08/20	14.1	2013/08/16	1.067
105158	2013/08/20	166.2°	21h59m	+ 1°	2013.08/12	13.8	2013/07/26	0.439
1683	2013/08/21	179.2°	22h 2m	-11°	2013/08/21	13.9	2013/08/18	1.247
5847	2013/08/22	168.8°	21h55m	- 0°	2013/08/25	14.4	2013/09/02	0.906
1638	2013/08/23	179.5°	22h 7m	-11°	2013/08/23	14.0	2013/08/16	1.310
1874	2013/08/24	178.8°	22h11m	- 9°	2013/08/24	13.4	2013/08/28	1.271
1902	2013/08/24	161.6°	22h42m	-28°	2013/08/24	14.0	2013/08/23	2.109
3768	2013/08/25	178.1°	22h20m	-12°	2013/08/25	14.4	2013/08/29	1.517
1668	2013/08/27	179.0°	22h23m	- 8°	2013/08/27	14.5	2013/08/29	1.214
330	2013/08/28	175.9°	22h33m	-13°	2013/08/28	14.5	2013/09/06	1.044
1133	2013/08/28	168.0°	22h48m	-20°	2013/08/29	13.6	2013/09/02	0.812
1387	2013/08/30	170.8°	22h19m	- 0°	2013/08/30	14.1	2013/08/27	0.786
839	2013/09/01	179.7°	22h41m	- 7°	2013/09/01	12.4	2013/08/29	1.225
3300	2013/09/01	157.0°	23h15m	-29°	2013/08/30	14.2	2013/08/26	1.682
4729	2013/09/01	175.1°	22h33m	- 3°	2013/09/01	14.4	2013/09/06	0.893
5913	2013/09/04	172.8°	22h43m	- 0°	2013/09/04	14.2	2013/09/04	1.114
6406	2013/09/06	174.6°	23h 8m	-11°	2013/09/06	13.9	2013/09/06	0.869
2409	2013/09/08	176.7°	23h14m	- 8°	2013/09/08	14.3	2013/09/07	0.829
394	2013/09/09	168.5°	23h30m	-15°	2013/09/09	12.0	2013/09/06	1.143
137126	2013/09/09	148.3°	21h13m	-18°	2013/08/26	14.4	2013/08/23	0.064
1270	2013/09/10	167.1°	23h36m	-16°	2013/09/10	13.7	2013/09/10	0.779
5851	2013/09/10	178.5°	23h17m	- 6°	2013/09/10	14.5	2013/09/03	1.274
736	2013/09/11	174.8°	23h27m	- 9°	2013/09/11	12.9	2013/09/08	0.839
324	2013/09/12	170.3°	23h12m	+ 5°	2013/09/13	8.2	2013/09/17	0.810
2231	2013/09/12	178.0°	23h18m	- 2°	2013/09/12	14.3	2013/09/14	1.063
435	2013/09/13	178.1°	23h28m	- 5°	2013/09/13	12.1	2013/09/13	1.068
955	2013/09/13	179.7°	23h25m	- 4°	2013/09/13	13.3	2013/08/31	1.199
709	2013/09/14	167.4°	23h12m	+ 8°	2013/09/14	12.5	2013/09/12	1.600
3855	2013/09/16	165.5°	0h 2m	-15°	2013/09/15	14.4	2013/09/12	0.787
4511	2013/09/16	172.7°	23h38m	- 9°	2013/09/15	13.8	2013/09/06	0.914
539	2013/09/17	167.6°	23h22m	+ 9°	2013/09/18	12.2	2013/09/19	1.187
542	2013/09/17	172.4°	23h54m	- 8°	2013/09/17	12.6	2013/09/17	1.513
2831	2013/09/18	170.4°	23h58m	-10°	2013/09/18	13.8	2013/09/17	0.788
418	2013/09/21	168.6°	23h36m	+ 9°	2013/09/21	12.6	2013/09/22	1.305
89	2013/09/23	156.4°	23h29m	+22°	2013/09/22	9.1	2013/09/21	1.128
1035	2013/09/24	179.7°	0h 6m	+ 0°	2013/09/24	13.5	2013/09/19	1.606
137	2013/09/26	172.8°	0h 0m	+ 7°	2013/09/26	11.5	2013/09/19	1.626
599	2013/09/26	156.9°	0h35m	-21°	2013/09/23	11.0	2013/09/19	1.030
479	2013/09/27	168.2°	0h37m	- 8°	2013/09/28	12.2	2013/10/02	1.236
1610	2013/09/29	179.2°	0h24m	+ 3°	2013/09/29	13.9	2013/09/30	0.767
994	2013/09/30	177.4°	0h24m	+ 5°	2013/09/30	12.7	2013/09/27	1.256
3284	2013/10/02	166.5°	0h53m	- 8°	2013/09/29	14.2	2013/09/18	0.792
2771	2013/10/03	171.8°	0h19m	+10°	2013/10/02	14.4	2013/09/25	1.186
12832	2013/10/03	179.9°	0h37m	+ 4°	2013/10/03	14.4	2013/10/03	0.776
14309	2013/10/03	175.8°	0h44m	+ 0°	2013/10/01	14.5	2013/09/05	0.613
128	2013/10/05	170.4°	0h58m	- 4°	2013/10/05	10.5	2013/10/04	1.418
176	2013/10/05	173.8°	0h30m	+ 9°	2013/10/05	11.4	2013/10/05	1.679
1653	2013/10/07	171.4°	0h39m	+13°	2013/10/08	12.6	2013/10/11	0.798
1719	2013/10/08	158.3°	0h25m	+26°	2013/10/08	13.8	2013/10/07	1.113
86	2013/10/10	172.4°	1h13m	- 0°	2013/10/10	11.7	2013/10/11	1.489
1627	2013/10/15	156.4°	1h48m	-14°	2013/07/07	12.5	2013/07/06	0.322
4905	2013/10/17	177.5°	1h35m	+ 7°	2013/10/17	14.3	2013/10/15	1.174
378	2013/10/18	174.4°	1h22m	+14°	2013/10/18	12.8	2013/10/17	1.431
989	2013/10/20	162.3°	1h 4m	+25°	2013/10/21	14.1	2013/10/24	1.058
358	2013/10/25	176.2°	2h 5m	+ 8°	2013/10/25	12.2	2013/10/27	1.503
6063	2013/10/25	147.7°	4h 4m	+ 2°	2013/11/08	12.3	2013/11/11	0.079
2212	2013/10/26	109.8°	21h54m	-22°	2013/10/05	14.1	2013/09/28	0.300
572	2013/10/27	172.9°	2h19m	+ 6°	2013/10/27	12.9	2013/10/25	1.037
26858	2013/10/28	167.7°	2h39m	+ 3°	2013/10/30	13.8	2013/11/09	0.716
1074	2013/10/31	179.7°	2h23m	+14°	2013/10/31	13.2	2013/11/02	1.637
3632	2013/11/04	175.4°	2h44m	+11°	2013/11/04	14.4	2013/11/12	0.999
941	2013/11/05	178.1°	2h45m	+14°	2013/11/05	14.0	2013/11/02	1.268
445	2013/11/06	148.5°	1h46m	+44°	2013/11/03	13.3	2013/11/01	1.738
1099	2013/11/06	172.6°	2h39m	+23°	2013/11/05	13.4	2013/10/30	1.437
138095	2013/11/09	110.9°	23h44m	-34°	2013/11/10	13.6	2013/11/10	0.126
216	2013/11/15	172.1°	3h35m	+11°	2013/11/15	9.5	2013/11/11	1.136
166	2013/11/19	159.0°	3h52m	- 1°	2013/11/17	12.6	2013/11/14	1.196
1125	2013/11/22	177.0°	3h52m	+17°	2013/11/22	14.5	2013/11/27	1.611
76	2013/11/23	178.1°	3h56m	+18°	2013/11/23	11.8	2013/11/25	1.947
3702	2013/11/23	154.8°	4h 6m	- 4°	2013/11/19	14.3	2013/11/14	1.172
6246	2013/11/24	169.3°	4h 3m	+31°	2013/11/25	14.3	2013/11/29	0.808
3737	2013/11/26	137.1°	1h34m	+51°	2013/11/07	14.2	2013/10/28	0.645
4925	2013/11/29	179.1°	4h21m	+20°	2013/11/29	14.4	2013/11/22	1.445
511	2013/12/01	163.7°	4h37m	+ 5°	2013/12/02	9.8	2013/12/03	1.629
1326	2013/12/01	163.7°	4h32m	+ 5°	2013/11/29	13.6	2013/11/24	1.227
505	2013/12/04	173.6°	4h42m	+15°	2013/12/04	10.6	2013/12/03	1.042
1539	2013/12/04	177.4°	4h43m	+19°	2013/12/04	14.0	2013/11/29	1.666
7731	2013/12/06	174.1°	4h51m	+28°	2013/12/06	14.4	2013/12/02	1.000
350	2013/12/07	168.6°	4h56m	+11°	2013/12/07	11.9	2013/12/06	1.646
899	2013/12/07	179.0°	4h54m	+21°	2013/12/06	13.1	2013/11/30	1.519
1626	2013/12/08	150.8°	3h50m	+48°	2013/12/08	12.0	2013/12/07	0.787
1792	2013/12/11	178.1°	5h13m	+24°	2013/12/11	14.1	2013/12/03	1.134
3106	2013/12/12	163.3°	5h17m	+ 6°	2013/12/11	14.1	2013/12/08	1.489
560	2013/12/13	174.0°	5h24m	+17°	2013/12/13	13.4	2013/12/16	1.361
3444	2013/12/13	166.8°	5h15m	+36°	2013/12/12	14.1	2013/12/09	0.920
3744	2013/12/15	175.6°	5h34m	+18°	2013/12/15	14.4	2013/12/09	0.968
5647	2013/12/16	156.3°	6h 5m	+ 0°	2013/12/18	13.8	2013/12/20	0.846
776	2013/12/22	174.0°	6h 7m	+29°	2013/12/22	11.1	2013/12/17	1.685
3169	2013/12/27	178.9°	6h22m	+22°	2013/12/27	13.6	2013/12/28	0.800

Table III. Numerical Sequence of Close Approaches

Planet	Max Elon D	Max E	RA	Dec	Br Mag D	Br Mag	Min Dist D	Min Dist
1627	2013/10/15	156.4°	1h48m	-14°	2013/07/07	12.5	2013/07/06	0.322
2212	2013/10/26	109.8°	21h54m	-22°	2013/10/05	14.1	2013/09/28	0.300
3752	2013/02/15	127.0°	13h34m	+29°	2013/02/13	13.3	2013/02/12	0.148
6063	2013/10/25	147.7°	4h 4m	+ 2°	2013/11/08	12.3	2013/11/11	0.079
7888	2013/05/14	115.6°	14h12m	+43°	2013/03/28	14.4	2013/03/20	0.126
17188	2013/06/24	153.8°	19h12m	- 1°	2013/06/16	13.7	2013/06/12	0.101
52762	2013/01/16	127.2°	11h23m	+ 6°	2013/01/27	13.6	2013/01/31	0.207
137126	2013/09/09	148.3°	21h13m	-18°	2013/08/26	14.4	2013/08/23	0.064
138095	2013/11/09	110.9°	23h44m	-34°	2013/11/10	13.6	2013/11/10	0.126
163364	2013/06/09	159.1°	15h39m	-22°	2013/05/27	13.9	2013/05/23	0.039

ASTEROID-DEEPSKY APPULSES IN 2013

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The following list is a very small subset of the results of a search for asteroid-deepsky appulses for 2013, presenting only the highlights for the year based on close approaches of brighter asteroids to brighter DSOs. The complete set of predictions is available at

http://www.minorplanet.info/ObsGuides/Appulses/DSOAppulses.htm

For any event not covered, the Minor Planet Center's web site at *http://scully.cfa.harvard.edu/cgi-bin/checkmp.cgi* allows you to enter the location of a suspected asteroid or supernova and check if there are any known targets in the area.

The table gives the following data:

Date/Time	Universal Date (MM DD) and Time of closest approach
#/Asteroid	The number and name of the asteroid
RA/Dec	The J2000 position of the asteroid
AM	The approximate visual magnitude of the asteroid
Sep/PA	The separation in arcseconds and the position angle from the DSO to the asteroid
DSO	The DSO name or catalog designation
DM	The approximate total magnitude of the DSO
DT	The type of DSO: OC = Open Cluster; GC = Globular Cluster; G = Galaxy
SE/ME	The elongation in degrees from the sun and moon respectively
MP	The phase of the moon: 0 = New, 1.0 = Full. Positive = waxing; Negative = waning

Date	UT	#	Name	RA	Dec	AM	Sep	PA	DSO	DM	DT	SE	ME	MP
01 12	16:49	14	Irene	12:26.90	+09 35.2	10.2	47	177	NGC 4417	11.1	G	110	120	+0.01
01 14	06:59	704	Interamnia	02:42.93	+28 33.4	11.0	34	38	NGC 1056	12.4	G	112	79	+0.09
02 08	23:22	13	Egeria	09:12.33	+45 00.9	10.2	177	6	NGC 2776	11.6	G	150	148	-0.02
02 14	**08:48**	**14**	**Irene**	**12:41.92**	**+11 38.8**	**9.5**	**156**	**266**	**M59**	**9.6**	**G**	**138**	**159**	**+0.19**
02 16	18:33	108	Hecuba	09:38.57	+17 00.2	12.5	110	193	NGC 2943	12.4	G	173	95	+0.40
03 19	14:30	14	Irene	12:25.18	+15 33.3	8.9	244	205	NGC 4379	11.7	G	163	93	+0.49
04 05	11:47	40	Harmonia	12:45.16	+03 02.6	9.9	92	201	NGC 4665	10.5	G	170	125	-0.25
04 14	21:41	471	Papagena	14:20.49	+04 00.9	11.8	305	16	NGC 5566	10.6	G	162	134	+0.18
04 15	04:58	471	Papagena	14:20.25	+04 01.9	11.8	180	16	NGC 5560	12.4	G	162	131	+0.21
04 16	09:22	119	Althaea	13:09.79	-07 45.1	12.2	337	30	NGC 4995	11.1	G	173	106	+0.30
05 02	18:24	96	Aegle	16:57.79	-44 52.0	12.3	322	158	NGC 6249	8.2	OC	139	63	-0.46
05 03	18:01	70	Panopaea	12:58.07	+01 39.8	12.1	290	355	NGC 4845	11.2	G	149	136	-0.36
05 05	00:03	39	Laetitia	12:34.31	+06 25.7	10.9	211	202	NGC 4532	11.9	G	140	157	-0.23
05 06	**22:19**	**22**	**Kalliope**	**12:31.03**	**+12 20.1**	**11.4**	**260**	**153**	**M87**	**8.6**	**G**	**134**	**160**	**-0.09**
05 07	04:36	22	Kalliope	12:30.92	+12 19.3	11.4	153	332	NGC 4486A	11.2	G	134	159	-0.08
05 07	**04:50**	**40**	**Harmonia**	**12:21.99**	**+04 30.6**	**10.7**	**98**	**356**	**M61**	**9.6**	**G**	**136**	**165**	**-0.07**
05 07	10:31	22	Kalliope	12:30.81	+12 18.4	11.5	165	332	MCG +02-32-1	11.2	G	134	157	-0.06
05 08	01:25	22	Kalliope	12:30.54	+12 16.3	11.5	258	150	NGC 4478	11.4	G	133	152	-0.04
06 03	06:19	14	Irene	12:08.39	+10 25.7	10.3	234	46	NGC 4124	11.4	G	105	160	-0.25
06 03	14:59	409	Aspasia	13:01.12	-13 28.9	11.4	223	121	NGC 4897	11.8	G	126	176	-0.22
06 06	05:55	22	Kalliope	12:27.03	+09 36.7	11.9	123	70	NGC 4417	11.1	G	107	132	-0.05
06 07	17:50	22	Kalliope	12:27.31	+09 26.0	11.9	8	68	NGC 4424	11.7	G	105	115	-0.01
07 05	12:41	89	Julia	23:54.16	+07 55.3	10.6	281	126	NGC 7782	12.2	G	102	72	-0.07
07 08	14:48	37	Fides	18:03.39	-27 59.7	11.7	340	182	NGC 6520	7.6	OC	164	159	+0.00
08 05	02:15	128	Nemesis	01:15.51	+00 57.4	11.8	327	179	NGC 450	11.5	G	115	95	-0.03
08 08	10:55	324	Bamberga	23:36.39	+00 17.6	9.2	104	257	NGC 7716	12.1	G	141	159	+0.03
09 04	03:47	44	Nysa	01:05.01	+02 03.1	10.6	301	142	IC 1613	9.2	G	146	130	-0.02
12 06	04:10	704	Interamnia	09:40.21	+03 32.9	11.8	359	259	NGC 2960	12.4	G	108	152	+0.14

2012 QG42: A SLOW ROTATOR NEA

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CCD photometric observations of the near-Earth asteroid 2012 QG42 were made by a collaboration of observers in the U.S. and Europe. The asteroid was found to be a slow rotator, having a synodic period of 24.22 ± 0.01 h based on a data set spanning nearly two weeks. The amplitude of the lightcurve was 1.18 ± 0.03 mag.

The near-Earth asteroid 2012 QG42 was discovered by the Catalina Sky Survey on 2012 Aug 26. Based on its spectral colors in the S- to Q-type range for which 0.24 is a typical albedo (Binzel, personal communication), the H magnitude of 20.8 suggests a diameter of about 200 meters. A few days after discovery, Michael Busch (private communications) contacted Warner to request photometry to determine a preliminary period to help plan radar observations. Observations were made on 2012 August 31 and showed a steady ascent of about 0.35 mag over three hours, suggestive of a period in excess of 12 hours. This was sufficient evidence for radar planning but it did not end the observing campaign.

Once the elongation of full moon became sufficient, observations were started again at PDO on September 6; that run covering more than six hours and showing an increase of more than 0.5 mag with indications of an approaching maximum. These results were sent out as part of discussion of the asteroid on the Minor Planet Mailing List (*http://tech.groups.yahoo.com/group/mpml/*), which prompted the other co-authors to contact Warner regarding data that they obtained. Some of the observers were in the Eastern Hemisphere and had observations on dates when PDO did not observe, which proved critical since the asteroid's period appeared to be commensurate with an Earth day, the PDO data alone suggesting 16-18 hours.

Table I shows a list of the team leads who contributed to the campaign and the equipment that was used. PDO observations were unfiltered with exposures starting at 120 sec in August but going down to 30 sec as the asteroid's motion increased and it brightened considerably. Exposures at Indian Hill (IHO) were 12-15 sec. Those at Poznan were 15 sec and those at San Marcello Pistoiese were 20 sec. With fast moving objects, a compromise must be found to avoid excessive trailing while trying to keep the exposure at or more than 10 seconds so that scintillation noise does not start to dominate.

Lead	Code	Telescope	Camera
Warner	PDO	0.5-m f/8.1	FLI-1001E
Baker	IHO	0.3-m f/5.1	ST-402ME
Bacci	SMPO	0.60-m f/4.0	Alta U6
Bartczak	POZAN	0.7-m, 0.4-m	iXon3, ST-8
Vorobjov	ISAC	0.61-m f/4.5	STL-1001E

Table I. Observers and Equipment.

Table II shows the observing circumstances for the dates within the campaign, which extended to mid-September. By that time, the phase angle had exceeded 50°. To avoid issues with evolving amplitude and lightcurve shape, and with the period well-established, the campaign was closed. The synodic period was found to be 24.22 ± 0.01 h with an amplitude of 1.18 ± 0.03 mag. A long period was confirmed by preliminary analysis of radar data as well (Benner, private communications).

The lightcurve has a somewhat asymmetric shape but this is probably due to the lack of complete coverage. The line is the 4th order Fourier fit to the data. To complete the curve would have required observations from longitudes equal to Australia or Japan. This might have changed the period slightly, but not significantly. The lightcurve data will be made available to the radar team

Code	Date	UT	Phase	L_{PAB}	B_{PAB}
PDO	Aug 31	05:03 08:36	16.1 15.9	346.5	-4.3
IASC	Sep 04	04:30 04:52	9.4	346.5	-2.6
IASC	Sep 06	04:50 05:10	4.4	346.0	-1.1
PDO	Sep 06	03:40 10:02	4.6 3.8	346.6 .45.9	-1.1 -0.9
IASC	Sep 07	04:41 05:10	1.3	345.5	-0.1
SMPO	Sep 07	22:25 23:23	1.6 1.7	345.0 344.9	0.7
SMPO	Sep 08	20:46 22:23	5.8 6.1	344.0	2.0 2.2
IASC	Sep 08	20:25 23:49	5.7, 6.4	344.0 343.9	2.0 2.3
SMPO	Sep 08	22:24 23:19	6.1 6.3	344.0 343.9	2.2
POZAN	Sep 08/09	21:47 00:55	6.0 6.7	344.0 343.8	2.1 2.3
PDO	Sep 09	02:27 09:31	7.0 8.7	343.7 343.3	2.5 3.0
IASC	Sep 09/10	19:42 01:18	11.3 12.9	342.7 342.3	3.9 4.4
POZAN	Sep 09/10	18:56 00:53	11.1 12.8	342.7 342.3	3.8 4.4
IASC	Sep 10	03:13 03:28	13.5 13.6	342.1	4.6 4.7
PDO	Sep 10	05:16 10:10	14.1 15.7	341.9 341.5	4.8 5.4
IASC	Sep 10/11	18:37 00:45	18.6 21.0	340.7 340.0	6.4 7.2
IHO	Sep 11	01:11 04:00	21.2 22.3	340.0 339.6	7.2 7.6
IASC	Sep 11	03:55 04:09	22.3 22.4	339.7 339.6	7.6
IASC	Sep 12	03:26 03:44	33.7 33.9	336.2	11.5 11.6
IHO	Sep 13	00:55 02:22	47.4 48.5	331.8 331.4	16.3 16.7

Table II. Observing circumstances. The UT column gives the earliest and latest UT time of observation. Phase is the solar phase angle at the two UT times. L_{PAB} and B_{PAB} are, respectively, the phase angle bisector longitude and latitude at the two UT times. If a single value is given, the value did not change during the range of observations.

headed by Marina Brozovic at JPL, who can create a combined data set with the radar data and so generate a better model for the asteroid.

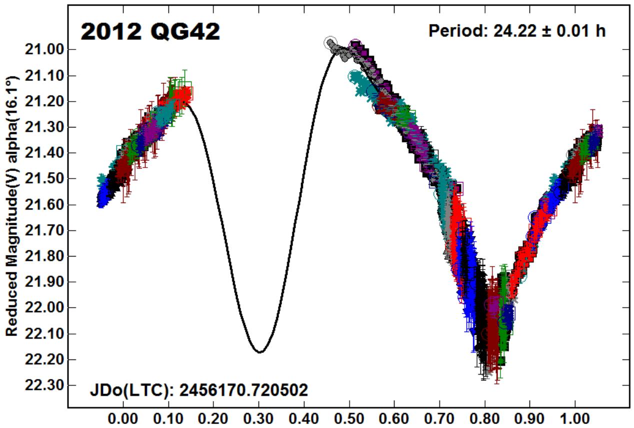

Figure 1. The lightcurve for 2012 QG42. More than 3100 data points were used, covering 2012 August 31 – September 13.

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ASTEROID LIGHTCURVE ANALYSIS AT THE PALMER DIVIDE OBSERVATORY: 2012 JUNE - SEPTEMBER

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Lightcurves for 10 asteroids were obtained at the Palmer Divide Observatory (PDO) from 2012 June to August: 1025 Riema, 1685 Toro, 3022 Dobermann, 6403 Steverin, 9564 Jeffwynn, (11904) 1991 TR1, (13186) 1996 UM, (23715) 1998 FK2, (53530) 2000 AV200, and (86257) 1999 TK207. Analysis of data from 2007 revised the previously reported period for (11904) 1991 TR1.

CCD photometric observations of 10 asteroids were made at the Palmer Divide Observatory (PDO) from 2012 June to September. See the introduction in Warner (2010) for a discussion of equipment, analysis software and methods, and overview of the lightcurve plot scaling. The “Reduced Magnitude” in the plots is Johnson V or Cousins R (indicated in the Y-axis title) corrected to unity distance by applying –5*log (rΔ) with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using G = 0.15 unless otherwise stated.

For the sake of brevity in the following discussions on specific asteroids, only some of the previously reported results are referenced. For a more complete listing, the reader is referred to the asteroid lightcurve database (LCDB, Warner *et al.*, 2009). The on-line version allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files, including the references with Bibcodes, is also available for download at *http://www.minorplanet.info/lightcurvedatabase.html*. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

1025 Riema. This Hungaria asteroid was previously worked by Shevchenko (2003), who found a period of 6.557 h. Subsequent work by Stephens (2003) found 3.580 h. Warner (2009) reported a period of 3.566 h. The latter data set was relatively sparse, which may explain the discrepancy with the Stephens period. The latest set of 195 data points gives a period of 3.581 h. The period spectrum included here, covering 3-7 h, indicates a strong preference for the 3.58 h solution over that from Shevchenko.

1685 Toro. Observations of this near-Earth asteroid (NEA) were made in July and August to support radar modeling. The period of about 10.195 h had been previously established on several occasions, e.g., Dunlap (1973) and Higgins (2008). The observations in late July were made at a phase angle of about 75°. At that time the amplitude of the lightcurve was 1.38 ± 0.02 mag and the synodic period was 10.226 ± 0.002 h. Additional observations in late August were at phase angle 97°, when the synodic period had decreased to 10.188 ± 0.002 h but the amplitude increased to 1.80 ± 0.02 mag. These are not unexpected changes with the increasing phase angle and will help the modeling process more than having just one curve or the other.

3022 Dobermann. This was the third apparition at which observations of this Hungaria asteroid were made. The period was found to be 10.32 h in 2004 (Warner, 2005) and 10.330 h in 2011 (Warner, 2011). Angeli (2001) found a period of 10.49 h, but none of the three data sets from PDO can be made to fit this solution. The results from the 2012 campaign were in close agreement with the two previous results from Warner.

6403 Steverin. This is a Eunomia family member that was worked by Warner (2005), who found a period of 3.485 h. The period of 3.4903 h found in 2012 is in good agreement with that result.

9564 Jeffwynn. This Mars-crosser was a “full moon project”, meaning it was bright enough while the moon was near full and other in-progress targets too faint. There were no previous results found in the LCDB.

(11904) 1991 TR1. This Hungaria asteroid was originally reported to have a period of 9.123 h (Warner, 2008) based on a monomodal curve and despite an amplitude of 0.31 mag. Harris (2012) has shown that at relatively low phase angles (6° in 2008), this combination is almost physically impossible and that a bimodal solution was the right solution. Another analysis of the 2007 data found a bimodal lightcurve with a period of 18.233 ± 0.003 h. The data in 2012 were of considerably less quality, being much fewer and noisier due to the asteroid being in crowded star fields. What data were available were forced to a period near the revised period. The result is not at all convincing. Observations at future apparitions are planned at PDO and encouraged elsewhere.

Number	Name	2012 (mm/dd)	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
1025	Riema (H)	08/20-08/25	195	8.3,8.7	325	12	3.581	0.002	0.10	0.01
1685	Toro	07/24-07/26	167	73.3,75.9	353,356	18	10.226	0.002	1.38	0.02
1685	Toro	08/13-08/17	167	95.1,97.5	25,32	24	10.188	0.002	1.80	0.02
3022	Dobermann (H)	08/26-09/10	305	12.5,15.0	331	17	10.333	0.001	0.87	0.02
6403	Steverin	07/16-07/23	274	10.5,10.4	298	19	3.4905	0.0003	0.47	0.02
9564	Jeffwynn	08/31-09/06	280	15.7,12.9	345	16	3.035	0.001	0.16	0.02
11904	1991 TR1 (H)	11/02-11/07*	308	7.6,4.2	49	-1	18.233	0.003	0.32	0.02
11904	1991 TR1 (H)	07/26-08/25	94	22.3,21.9,23.8	314	30	18.34	0.05	0.11	0.02
13186	1996 UM (H)	07/21-07/24	128	20.4,20.0	308	30	4.304	0.002	0.69	0.02
23715	1998 FK2 (H)	06/27-07/16	140	22.2,21.9,22.2	285	32	7.436	0.002	0.27	0.02
53530	2000 AV200 (H)	07/16-07/21	59	20.5,22.1	262	16	3.628	0.002	0.26	0.02
86257	1999 TK207 (H)	07/12-0726	428	14.9,11.0	311	11	32.408	0.005	1.51	0.02

* 2007

Table I. Observing circumstances. Asteroids with (H) after the name are members of the Hungaria group/family. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

(13186) 1996 UM and (23715) 1998 FK2. No previous results were found in the LCDB for these two Hungarias.

(53530) 2000 AV200. The plot for this Hungaria is for one of several possible periods between 3-4 hours. The period spectrum shows that periods of 3.374 and 3.932 h cannot be formally excluded. However, the plot at 3.628 h shows a better overall shape in terms of symmetry. No previous results were listed in the LCDB.

(86257) 1999 TK207. The period of 32.408 ± 0.005 h is in good agreement with the one of 32.49 h (Warner, 2011) given the sparser data set and gaps in coverage for the earlier result.

Acknowledgements

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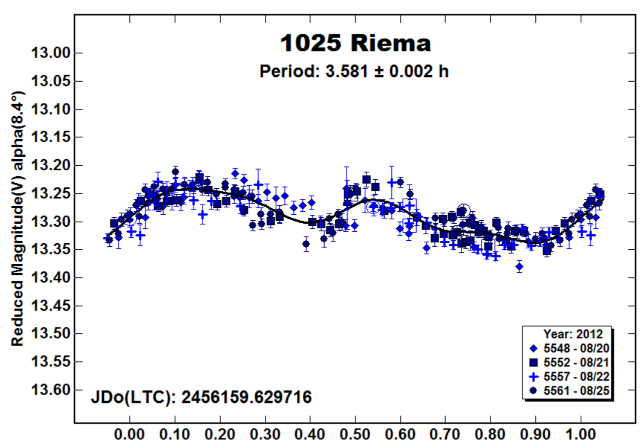

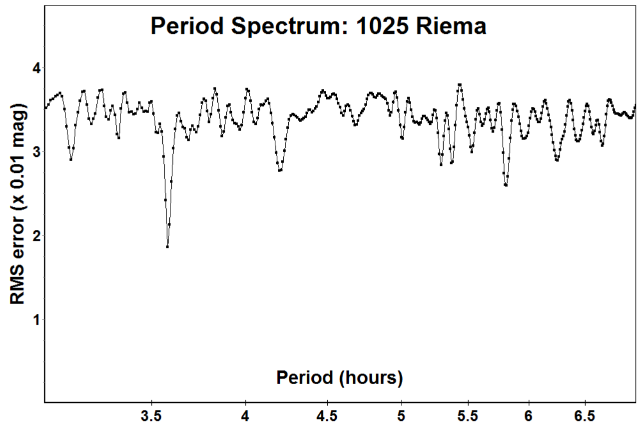
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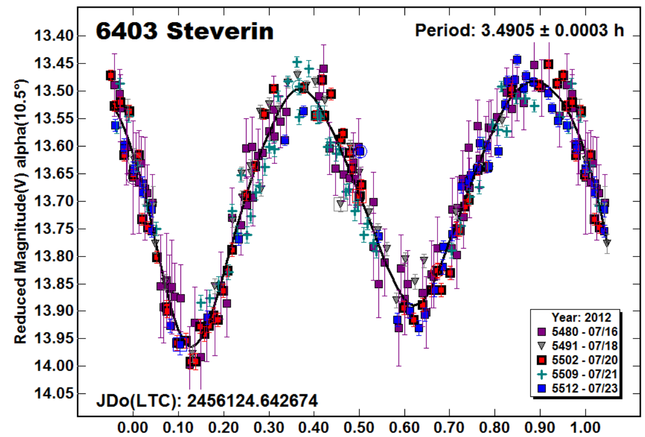
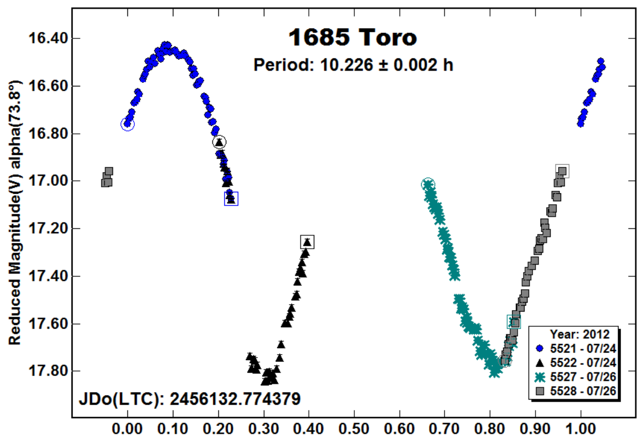
RMS error (x 0.01 mag)
Period (hours)


6403 Steverin
Period: 3.4905 ± 0.0003 h
Reduced Magnitude(V) alpha(10.5°)
Year: 2012
5480 - 07/16
5491 - 07/18
5502 - 07/20
5509 - 07/21
5512 - 07/23
JDo(LTC): 2456124.642674


1685 Toro
Period: 10.226 ± 0.002 h
Reduced Magnitude(V) alpha(73.8°)
Year: 2012
5521 - 07/24
5522 - 07/24
5527 - 07/26
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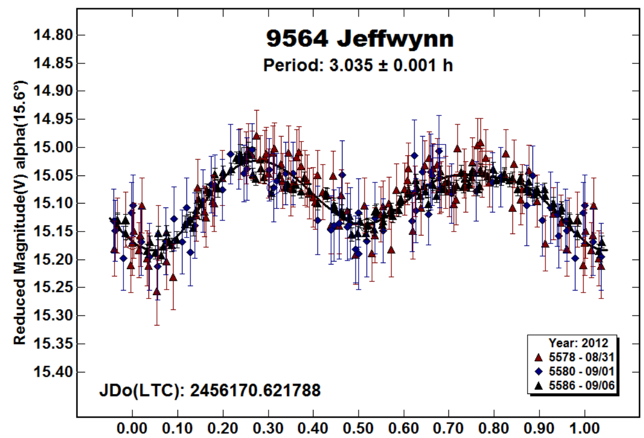
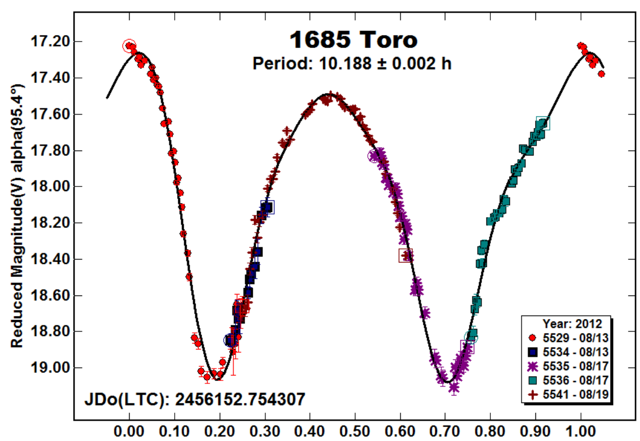
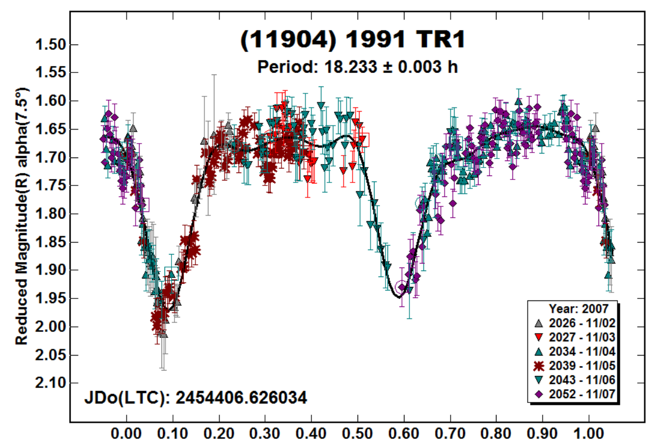
JDo(LTC): 2456132.774379


9564 Jeffwynn
Period: 3.035 ± 0.001 h
Reduced Magnitude(V) alpha(15.6°)
Year: 2012
5578 - 08/31
5580 - 09/01
5586 - 09/06
JDo(LTC): 2456170.621788


1685 Toro
Period: 10.188 ± 0.002 h
Reduced Magnitude(V) alpha(95.4°)
Year: 2012
5529 - 08/13
5534 - 08/13
5535 - 08/17
5536 - 08/17
5541 - 08/19
JDo(LTC): 2456152.754307


(11904) 1991 TR1
Period: 18.233 ± 0.003 h
Reduced Magnitude(R) alpha(7.5°)
Year: 2007
2026 - 11/02
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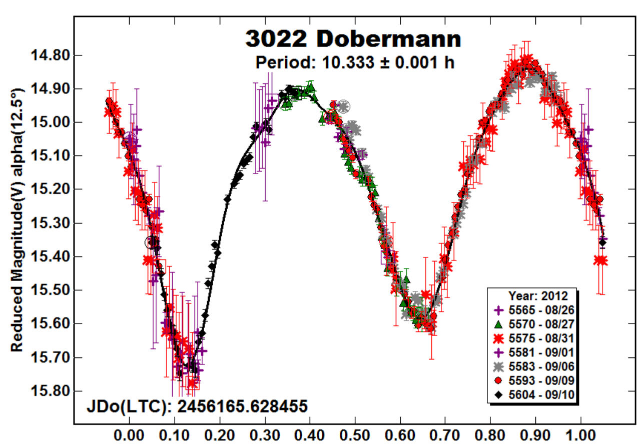
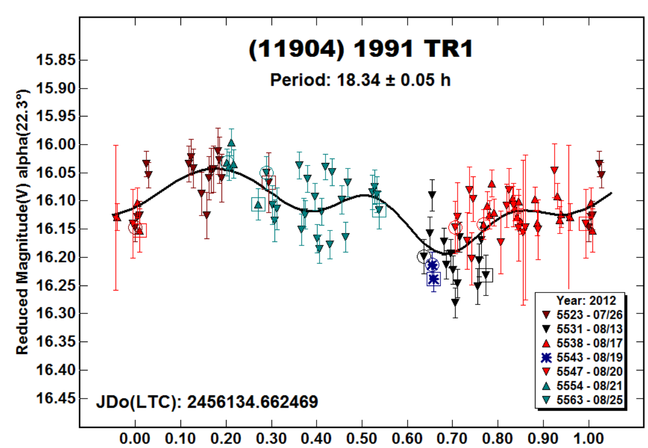
2034 - 11/04
2039 - 11/05
2043 - 11/06
2052 - 11/07
JDo(LTC): 2454406.626034


3022 Dobermann
Period: 10.333 ± 0.001 h
Reduced Magnitude(V) alpha(12.5°)
Year: 2012
5565 - 08/26
5570 - 08/27
5575 - 08/31
5581 - 09/01
5583 - 09/06
5593 - 09/09
5604 - 09/10
JDo(LTC): 2456165.628455


(11904) 1991 TR1
Period: 18.34 ± 0.05 h
Reduced Magnitude(V) alpha(22.3°)
Year: 2012
5523 - 07/26
5531 - 08/13
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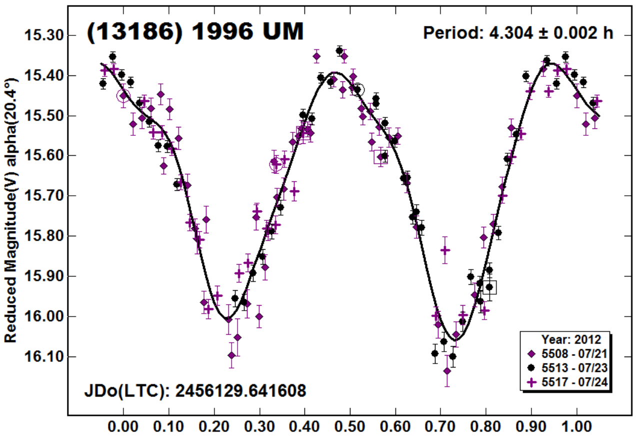
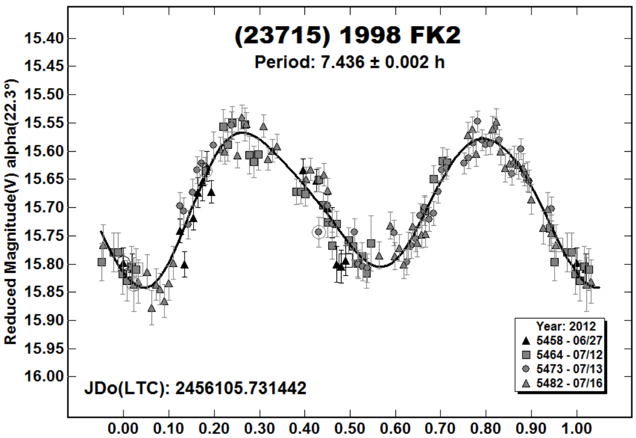
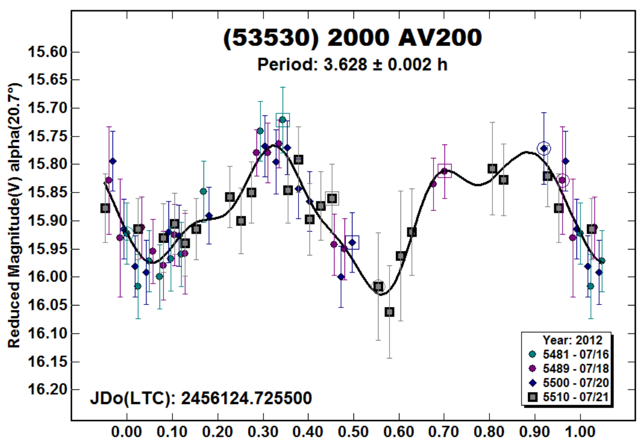
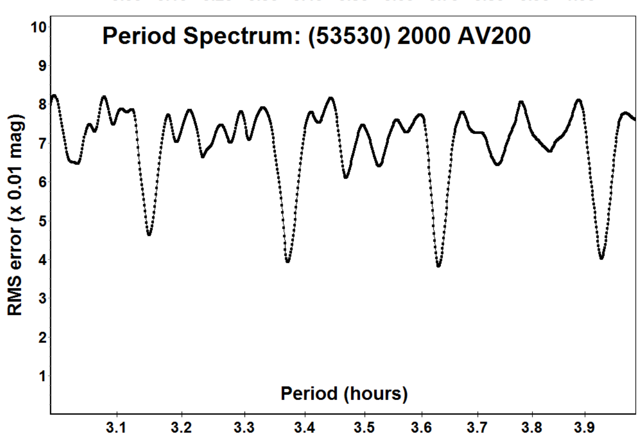
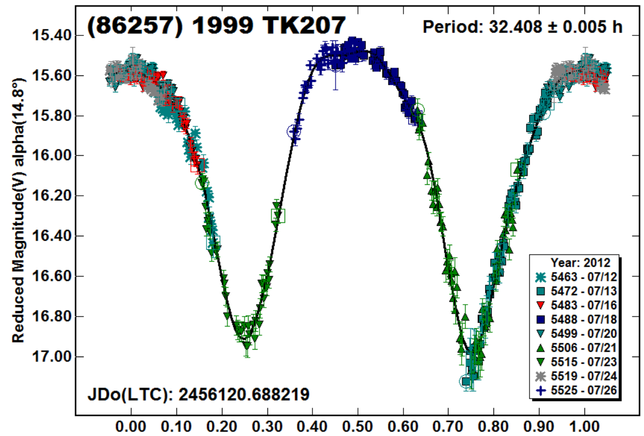
5543 - 08/19
5547 - 08/20
5554 - 08/21
5563 - 08/25
JDo(LTC): 2456134.662469











PERIOD DETERMINATION FOR THE SLOW ROTATOR 1954 KUKARKIN

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Lightcurve analysis for 1954 Kukarkin was performed from observations during its 2012 opposition. The synodic rotation period was found to be 136.40 ± 0.03 h and the lightcurve amplitude was 0.80 ± 0.05 mag.

The main-belt asteroid 1954 Kukarkin was discovered in 1952 and named in honor of the prominent Soviet astronomer Boris Vasilevich Kukarkin (1909-1977). He was the initiator and one of the compilers of the *General Catalogue of Variable Stars*, served as Vice President of the Astronomical Council of the U.S.S.R. Academy of Sciences from 1947 to 1960, as Vice President of the IAU from 1955 to 1961, and as President of IAU Commission 27 from 1951 to 1958.

1954 Kukarkin appeared in the 2012 April-June list of asteroid photometry opportunities for objects reaching a favorable apparition and having no or poorly-defined lightcurve parameters (Warner *et al*., 2012). Unfiltered CCD photometric images were taken at Observatorio Los Algarrobos, Salto, Uruguay (MPC Code I38) from 2012 June 23 through July 28 using a 0.3-m Meade LX-200R reduced to f/6.9. The CCD imager was a QSI 516wsg NABG (non-antiblooming gate) with a 1536 x 1024 array of 9-micron pixels. 2x2 binning was used, yielding an image scale of 1.77 arcseconds per pixel. Imaging exposures increased from 60 to 120 seconds as the asteroid faded past opposition (see Table I). The camera was always worked at –15°C and off-axis guided by means of a SX Lodestar camera and *PHD Guiding* (Stark Labs) software. All images were dark and flat-field corrected and then measured using *MPO Canopus* (Bdw Publishing) version 10.4.0.20 with a differential photometry technique. The data were light-time corrected. Night-to-night zero point calibration was accomplished by selecting up to five comp stars with near solar colors according to recommendations by Warner (2007) and Stephens (2008). Period analysis was also done with *MPO Canopus*, which incorporates the Fourier analysis algorithm developed by Harris (Harris *et al*., 1989).

A total of 25 nights were exclusively devoted to observe this asteroid over a total span of 36 days, making it by far our longest one-target campaign. About 133 hours of effective observation and more than 5,400 data points were required in order to solve a noisy lightcurve obtained from a heavily contaminated star background. Over the span of observations, the phase angle varied from 2.14º to 16.90º, the phase angle bisector ecliptic longitude from 268.9º to 270.3º, and the phase angle bisector ecliptic latitude from –3.1º to 0.0º.

The rotational period for 1954 Kukarkin was determined (for the first time) to be 136.40 ± 0.03 h along with a peak-to-peak amplitude of 0.80 ± 0.05 mag. The period spectrum showed three other plausible solutions (68.15 h, 204.69 h, and 272.93 h, those being, respectively, half, 3/2, and twice the adopted period. All of them were almost equally acceptable mathematically. However, not only were the three solutions slightly worse than the chosen period, given the amplitude of 0.8 mag and low phase angle, they also represented physically unlikely asteroid lightcurves, i.e., monomodal, trimodal, or a complex quadramodal.

Harris (1994) found that small and slow rotating asteroids might show tumbling motion. Despite the fact that the mean diameter of 1954 Kukarkin is not actually known, it is conceivable that given its long period it could be a non-principal axis rotator (NPAR). However, no clear evidence of tumbling was seen in the lightcurve. Unfortunately, the tumbling likelihood was not further investigated since the analysis software used (*MPO Canopus*) is capable of handling only summed curves (the typical case for a binary asteroid) but not the product from two rotation actions (the typical case for a tumbling asteroid). Therefore, whether or not 1954 Kukarkin is a tumbler still remains an open question.

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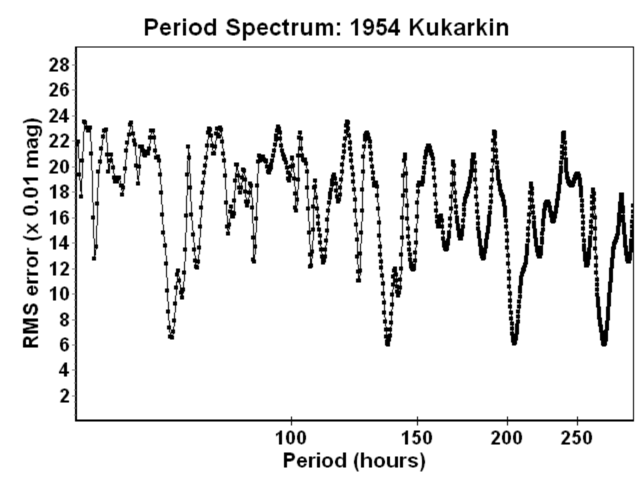
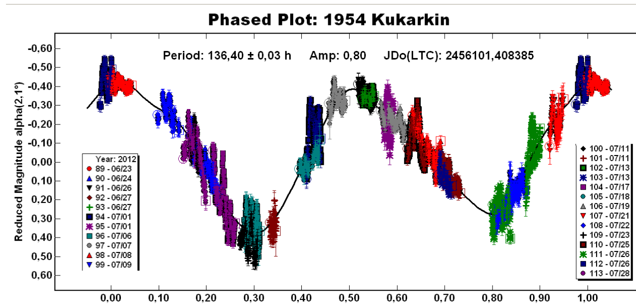
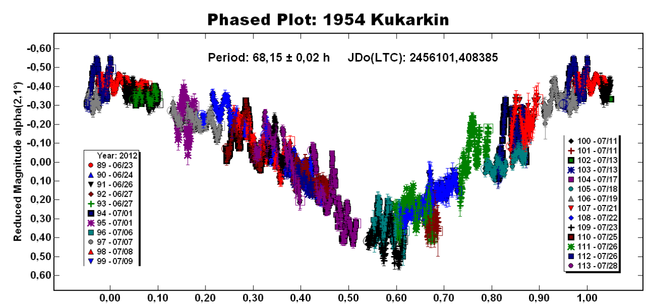
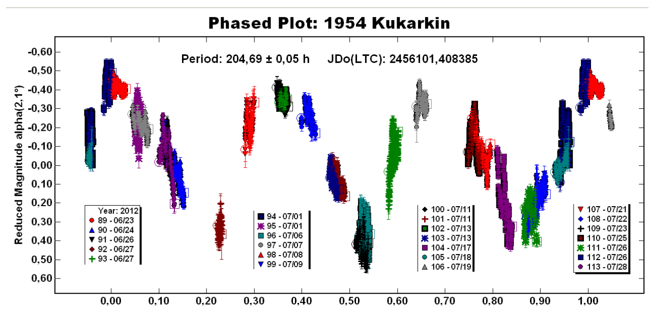
Sessions	Dates	Exp	Phase	V mag
89-96	06/23-07/06	60	2.1-7.7	14.5-14.8
97-101	07/07-07/12	80	8.2-10.4	14.8-14.9
102-108	07/13-07/22	100	10.9-14.7	14.9-15.1
109-113	07/23-07/28	120	15.0-16.9	15.1-15.2

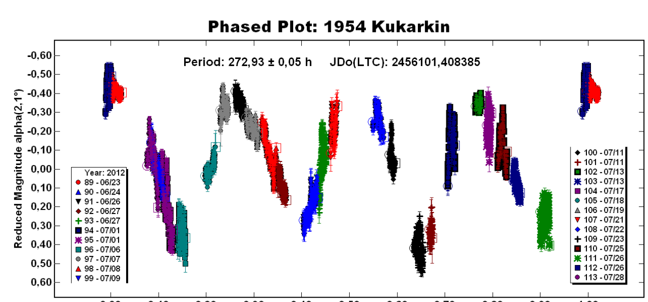
Table I. Observing circumstances. All dates are in 2012. The exposure times are in seconds.











ROTATION PERIOD DETERMINATION FOR 612 VERONIKA

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(Received: 3 October)

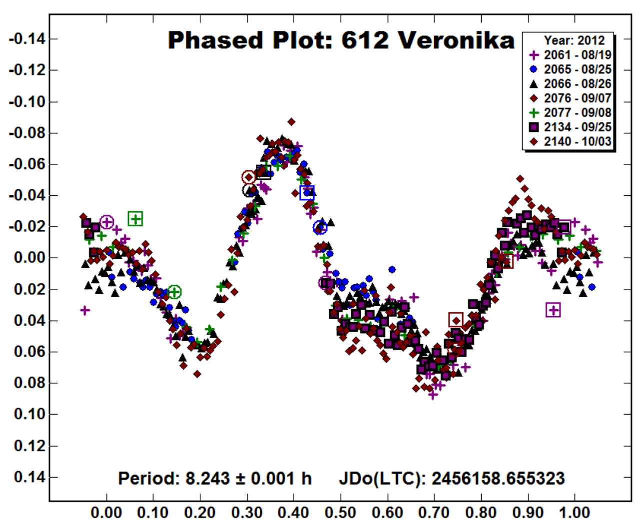
For 612 Veronika we find a synodic rotation period of 8.243 ± 0.001 hours and an amplitude of 0.14 ± 0.02 magnitudes.

Observations by F. Pilcher were obtained with a Meade 35 cm LX 200 GPS S-C, SBIG STL 1001-E CCD, clear filter, unguided exposures. Those by A. Ferrero were with a 30 cm f/8 Ritchey-Chretien and SBIG ST9 CCD. Image measurement, lightcurve analysis, and sharing of data were done with *MPO Canopus* software.

The Asteroid Lightcurve Data Base (Warner et. al. 2012) presents no previous photometric observations of 612 Veronika. This object was assigned high priority by the authors because it is brighter at its 2012 opposition than at any time for the next several years. From observations on seven nights 2012 Aug. 19 - Oct. 3 the authors find a synodic rotation period 8.243 ± 0.001 hours, amplitude 0.14 ± 0.02 magnitudes.

References

Warner, B. D., Harris, A. W., and Pravec, P. (2012). "Asteroid Lightcurve Data File: June 24, 2012" *http://www.MinorPlanetObserver.com/astlc/default.htm*



ROTATIONAL PERIOD OF FIVE ASTEROIDS

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Observations from 2012 May to August lead to lightcurve period determinations for five asteroids: 130 Elektra, P = 5.225 ± 0.001 h; 456 Abnoba, P = 18.281 ± 0.001 h; 676 Melitta, P=16.767 ± 0.003 h; 979 Ilsewa P = 42.97 ± 0.01 h; and 3443 Leetsungdao, P = 3.440 ± 0.001 h.

During a period of four months in 2012, the Bigmuskie Observatory measured the rotation period of five asteroids. All the targets were worked with a Marcon 0.3-m f/8 Ritchey-Chretien with an SBIG ST-9 CCD camera, which has a pixel array of 512x512x20 microns. The field of view (FOV) was about 15x15 arcminutes with a resolution of 1.7 arcseconds/pixel. All images were taken with an *Astrodon* Rc filter. Acquisition of the images was performed using *CCDSoft V5* together with *TheSky6*. Image reduction and photometry were carried out with *MPO Canopus* v10. The Comparison Star Selector in *MPO Canopus* was used for all the sessions, which allowed using only solar-color comparison stars. This allowed a linkage between the sessions on the order of ±0.05 mag in most cases.

130 Elektra. This was an easy target, having a large amplitude and signal-to-noise (SNR). Only two sessions were necessary to reach the result of a 5.225 ± 0.001 h and an amplitude of 0.30 mag.

456 Abnoba. After seven sessions, a secure result appeared with a period of 18.281 ± 0.001 h and an amplitude of 0.32 mag.

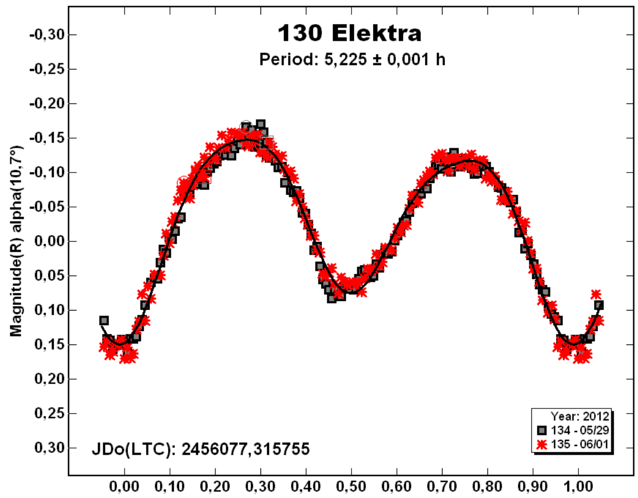
676 Melitta. Based on the period spectrum, the correct period seems to be 16.767 ± 0.003 h with an amplitude of 0.08 mag. Two other periods were also possible: 8.393 ± 0.002 h and 12.420 ± 0.003 h. Small misfits in the linkage between the sessions led to rejection of these solutions and to concentrate on the 16 hour period.

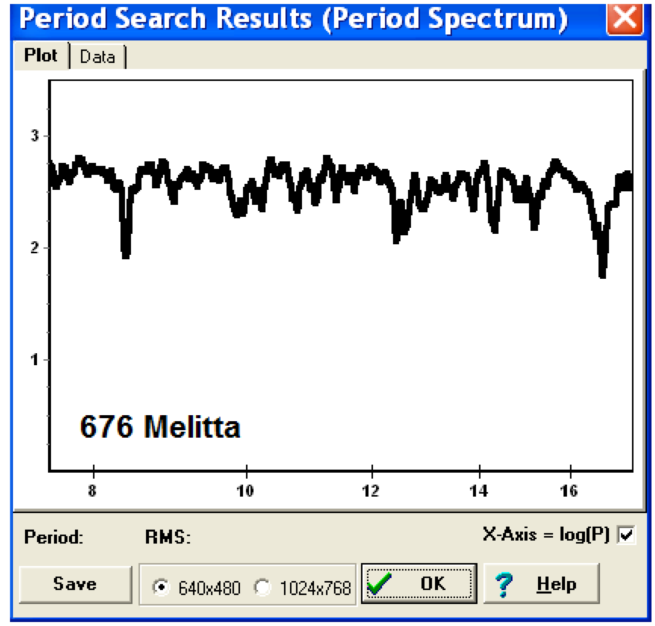
979 Ilsewa. Even with the Comparison Star Selector, some sessions required large shifts to fit the curve. In particular, sessions 205, 209, and 211 required a shift of 0.10 mag, a value usually out of the error range of the CSS. Despite this, the solution of 42.97 ± 0.01 h and an amplitude of 0.31 mag appears to be secure.

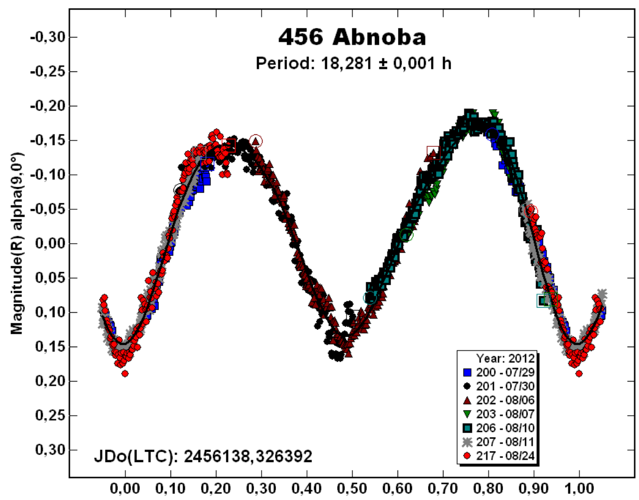
3443 Leetsungdao. After three sessions, the result was a period of 3.440 ± 0.001 h and an amplitude of 0.33 mag.

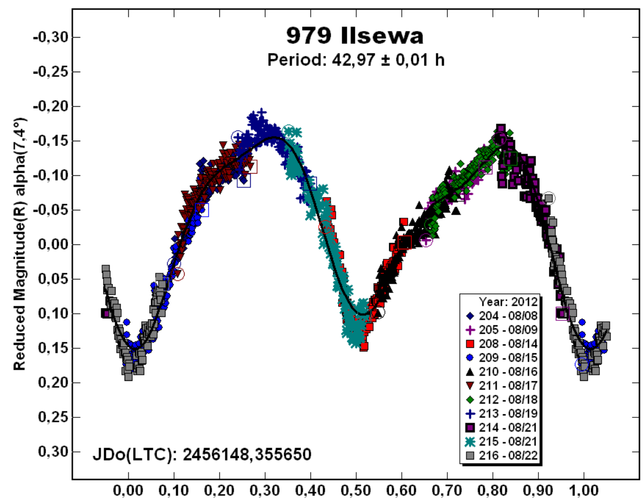
References

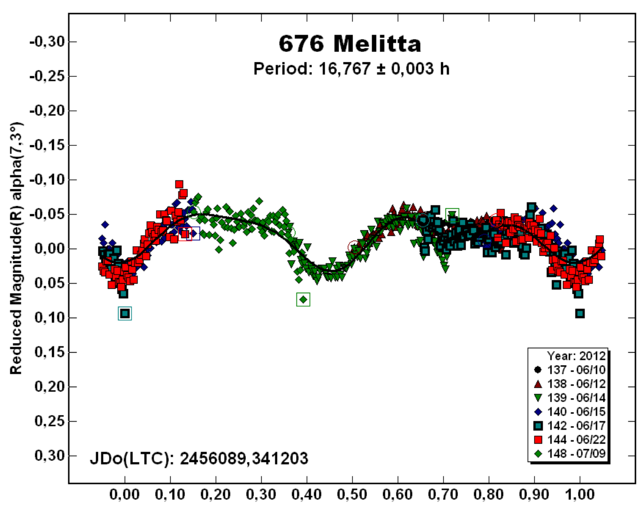
Warner, B. D. (2012). MPO Software, Canopus version 10.4.0.20. Bdw Publishing, Colorado Springs, CO.


130 Elektra
Period: 5,225 ± 0,001 h
Magnitude(R) alpha(10,7°)
JDo(LTC): 2456077,315755
Year: 2012
134 - 05/29
135 - 06/01


Period Search Results (Period Spectrum)
Plot
Data
676 Melitta
Period:
RMS:
X-Axis = log(P)
Save
640x480
1024x768
OK
Help


456 Abnoba
Period: 18,281 ± 0,001 h
Magnitude(R) alpha(9,0°)
JDo(LTC): 2456138,326392
Year: 2012
200 - 07/29
201 - 07/30
202 - 08/06
203 - 08/07
206 - 08/10
207 - 08/11
217 - 08/24


979 Ilsewa
Period: 42,97 ± 0,01 h
Reduced Magnitude(R) alpha(7,4°)
JDo(LTC): 2456148,355650
Year: 2012
204 - 08/08
205 - 08/09
208 - 08/14
209 - 08/15
210 - 08/16
211 - 08/17
212 - 08/18
213 - 08/19
214 - 08/21
215 - 08/21
216 - 08/22


676 Melitta
Period: 16,767 ± 0,003 h
Reduced Magnitude(R) alpha(7,3°)
JDo(LTC): 2456089,341203
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137 - 06/10
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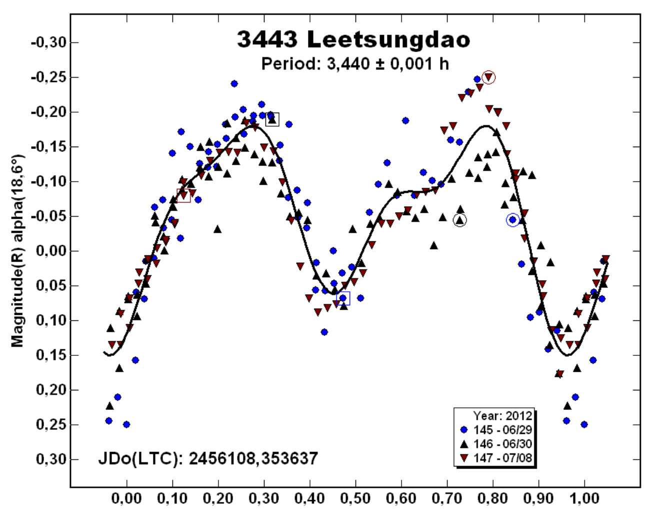
144 - 06/22
148 - 07/09


3443 Leetsungdao
Period: 3,440 ± 0,001 h
Magnitude(R) alpha(18,6°)
JDo(LTC): 2456108,353637
Year: 2012
145 - 06/29
146 - 06/30
147 - 07/08

LIGHTCURVES AND DERIVED ROTATION PERIODS FOR 18 MELPOMENE, 38 LEDA, AND 465 ALEKTO

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(Received: 4 October)

From new lightcurves obtained near their 2012 oppositions rotation periods and amplitudes are found for 18 Melpomene 11.571 ± 0.001 hours, 0.34 ± 0.02 magnitudes at phase angles 26 to 28 degrees; 38 Leda 12.837 ± 0.001 hours, 0.14 ± 0.02 magnitudes; 465 Alekto 10.938 ± 0.001 hours with three very unequal maxima, 0.12 ± 0.02 magnitudes.

All observations reported here were made at the Organ Mesa Observatory using a Meade 35-cm LX-200 GPS Schmidt-Cassegrain (SCT), SBIG STL-1001E CCD, red filter for bright 18 Melpomene, clear filter for the other targets. Exposures were unguided. Analysis used differential photometry only. Image measurement and lightcurve analysis were done by *MPO Canopus*. Because of the large number of data points, the data for the lightcurves presented here have been binned in sets of three points with a maximum time interval between points no greater than 5 minutes.

18 Melpomene. Warner et al. (2012) state a secure synodic rotation period of 11.570 hours based on several consistent published values. In addition Torppa et al. (2003) presented a lightcurve inversion model. J. Durech (2012, personal communication) stated that this model is not fully reliable, and for this reason is not presented on the DAMIT website (http://astro.troja.mff.cuni.cz/projects/asteroids3D). To provide data to improve the Torppa et al. (2003) model, observations were obtained, all of them after opposition at phase angles 26 to 28 degrees, on 14 nights 2012 Aug. 29 - Sept. 24. These provide full phase coverage and a good fit to an 11.571 ± 0.001 hour rotation period with amplitude 0.34 ± 0.02 magnitudes. This is consistent with previous published values.

38 Leda. Warner et al. (2012) state a secure synodic rotation period of 12.838 hours based on several consistent published values. To provide additional data for a lightcurve inversion model, observations were obtained on 7 nights 2012 June 4 - 29. These provide full phase coverage and a good fit to a 12.837 ± 0.001 hour rotation period with amplitude 0.14 ± 0.02 magnitudes. This is consistent with previous published values.

465 Alekto. Warner et al. (2012) do not list a previously published rotation period. Observations were obtained on 9 nights 2012 Aug. 21 - Oct. 4. These provide full phase coverage and a good fit to a 10.938 ± 0.001 hour rotation period with amplitude 0.12 ± 0.02 magnitudes. The lightcurve is irregular with three maxima per cycle which are nearly evenly spaced in time but very unequal in height.

References

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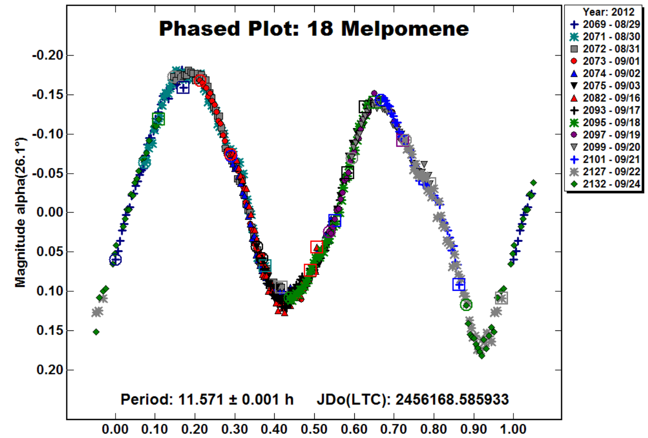

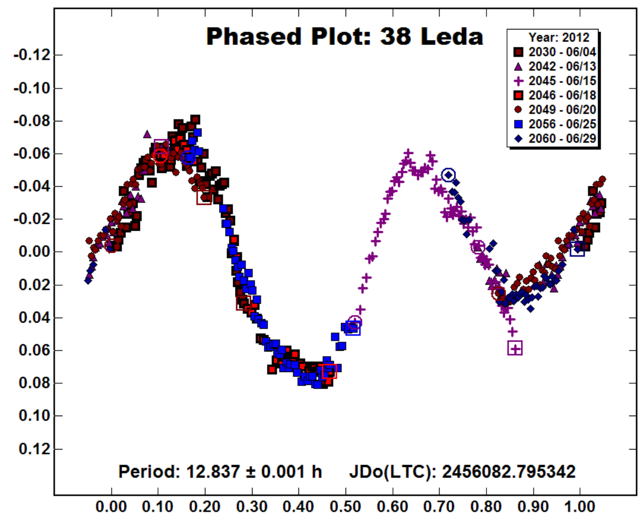

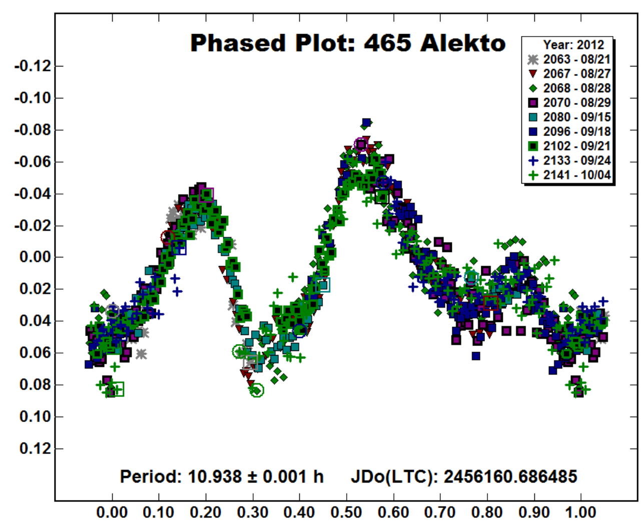

ASTEROIDS OBSERVED FROM SANTANA AND CS3 OBSERVATORIES: 2012 JULY - SEPTEMBER

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Lightcurves of six asteroids were obtained from Santana Observatory and the Center for Solar System Studies (CS3): 602 Marianna, 979 Ilsewa, 995 Sternberga, 1330 Spiridonia, 1332 Marconia, and 2763 Jeans.

Observations were made at Santana Observatory (MPC Code 646) using a 0.30-m Schmidt-Cassegrain (SCT) with a SBIG STL-1001E CCD camera and CS3 using a 0.40-m or 0.35-m SCT with a SBIG STL-1001E CCD camera. All images were unguided and unbinned with no filter. Measurements were made using *MPO Canopus*, which employs differential aperture photometry to produce the raw data. Period analysis was done using *Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). The asteroids were selected from the list of asteroid photometry opportunities published on the Collaborative Asteroid Lightcurve Link (CALL) website (Warner et al., 2012). 995 Sternberga and 1330 Spiridonia were selected to refine results previously obtained by the author.

The results are summarized in the table below, as are individual plots. Night-to-night calibration of the data (generally < ±0.05 mag) was done using field stars converted to approximate Cousins V magnitudes based on 2MASS J-K colors (Warner 2007 and Stephens 2008) or in some cases by using the APASS release 6 catalog.

602 Marianna. Observations on August 10, 11, 18, 25 and 26 were acquired at CS3. All others were acquired at Santana Observatory. Lagerkvist (1992) obtained observations over three nights in 1990. A period could not be determined but the observations suggested a period over 30 h. Teng (Behrend 2012) obtained data on three nights in June 2003 reporting a period of 34 h which is in fair agreement with this result.

979 Ilsewa. Observations on August 10 and 11 were acquired at CS3. All others were acquired at Santana Observatory. The LCDB (Warner et al., 2012) contains a reference from a 2001 result from Behrend with a reported period of 19 h which can no longer be found on that website (Behrend 2012).

995 Sternberga. Images on June 29/30 and July 15 were acquired at CS3. All others were acquired at Santana. The author (Stephens 2005A) observed Sternberga in 2004 and this updates that result of 15.26 h. The observations from 2004 were re-measured using the APASS R6 catalog. The period spectrum of the re-measured 2004 observations revealed strong aliases at 14.6 h, 15.3 or 15.8 h. The 14.62 h period with an amplitude of less than 0.1 magnitudes is preferred. Given this re-determined 2004 synodic period and the lack of aliases in the 2012 lightcurves; the 14.612 h synodic period is preferred.

1330 Spiridonia. All observations were obtained at CS3. Spiridonia was observed by the author in 2005 (Stephens 2005B) with a reported period of 9.67 h, in agreement with this result. Manzini (Behrend 2012) obtained a partial lightcurve over two nights in February 2004 and reported a period of 32.7 h.

1332 Marconia. All images were acquired at Santana Observatory. This asteroid does not have a previously reported period in the LCDB (Warner et al., 2012).

2763 Jeans. All images were acquired at Santana Observatory. This asteroid does not have a previously reported period in the LCDB (Warner et al., 2012).

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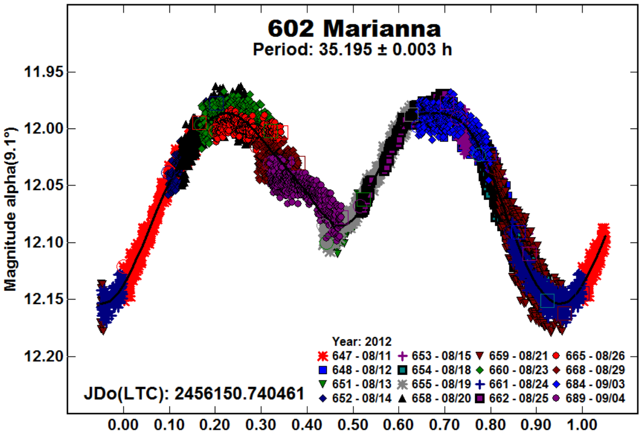
#	Name	mm/dd/12	Data Pts	α	L_{PAB}	B_{PAB}	Per (h)	PE	Amp (mag)	AE
602	Marianna	08/11 – 09/04	4,790	9.2, 1.2, 2.5	337	2	35.195	0.003	0.17	0.03
979	Ilsewa	07/30 – 08/12	1,942	10,1, 6.7	327	13	42.61	0.01	0.30	0.03
995	Sternberga	06/30 – 07/15	806	11.0, 9.3	291	17	14.612	0.002	0.20	0.03
1330	Spiridonia	07/15 – 07/28	768	9.5, 3.8	310	10	9.626	0.002	0.08	0.02
1332	Marconia	08/27 – 09/11	846	8.7, 2.1	353	-1	19.16	0.01	0.30	0.03
2763	Jeans	09/25 – 09/27	531	8.8, 7.7	14	5	7.805	0.005	0.16	0.02


602 Marianna
Period: 35.195 ± 0.003 h
Magnitude alpha(9.1°)
Year: 2012
647 - 08/11
648 - 08/12
651 - 08/13
652 - 08/14
653 - 08/15
654 - 08/18
655 - 08/19
658 - 08/20
659 - 08/21
660 - 08/23
661 - 08/24
662 - 08/25
665 - 08/26
668 - 08/29
684 - 09/03
689 - 09/04
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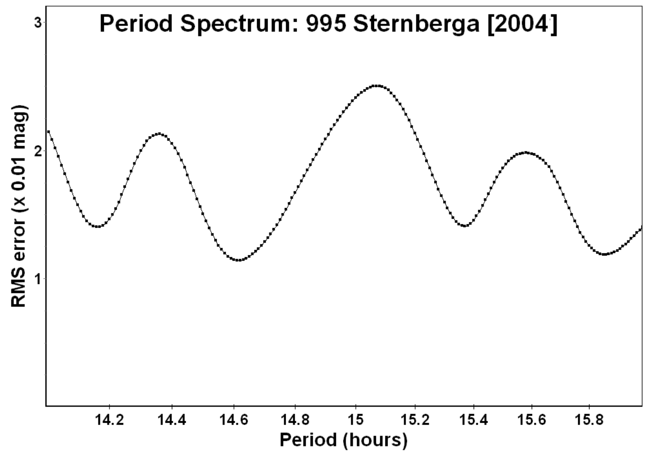
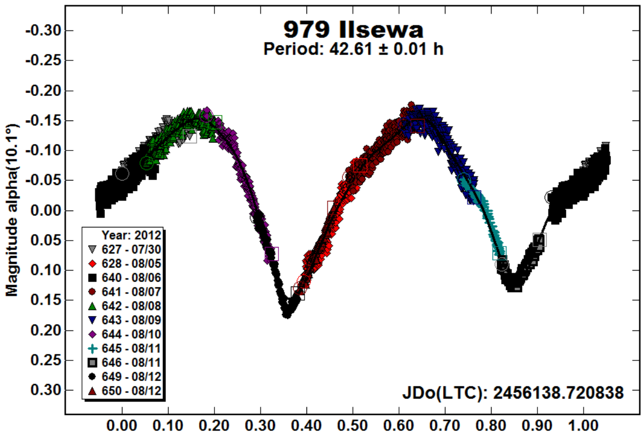
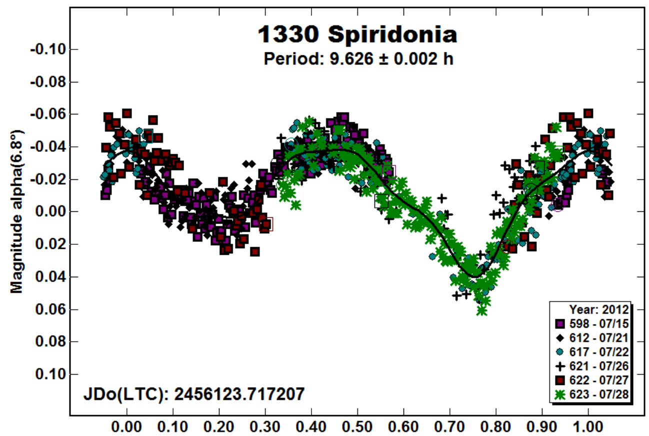

Period Spectrum: 995 Sternberga [2004]
RMS error (x 0.01 mag)
Period (hours)


979 Ilsewa
Period: 42.61 ± 0.01 h
Magnitude alpha(10.1°)
Year: 2012
627 - 07/30
628 - 08/05
640 - 08/06
641 - 08/07
642 - 08/08
643 - 08/09
644 - 08/10
645 - 08/11
646 - 08/11
649 - 08/12
650 - 08/12
JDo(LTC): 2456138.720838


1330 Spiridonia
Period: 9.626 ± 0.002 h
Magnitude alpha(6.8°)
Year: 2012
598 - 07/15
612 - 07/21
617 - 07/22
621 - 07/26
622 - 07/27
623 - 07/28
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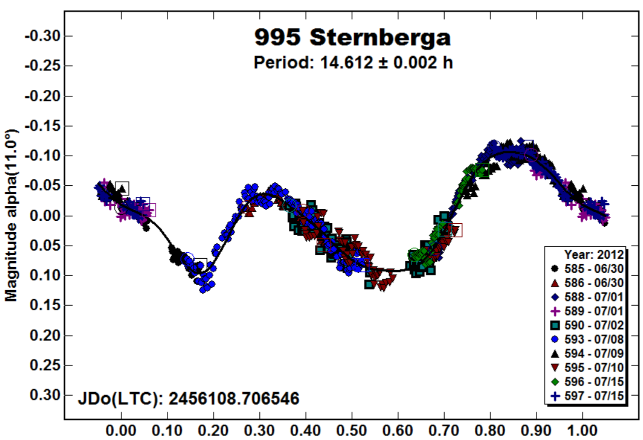
995 Sternberga
Period: 14.612 ± 0.002 h
Magnitude alpha(11.0°)
Year: 2012
585 - 06/30
586 - 06/30
588 - 07/01
589 - 07/01
590 - 07/02
593 - 07/08
594 - 07/09
595 - 07/10
596 - 07/15
597 - 07/15
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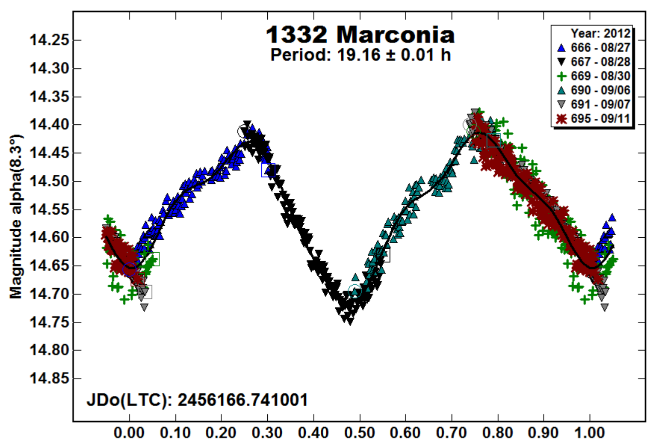
1332 Marconia
Period: 19.16 ± 0.01 h
Magnitude alpha(8.3°)
Year: 2012
666 - 08/27
667 - 08/28
669 - 08/30
690 - 09/06
691 - 09/07
695 - 09/11
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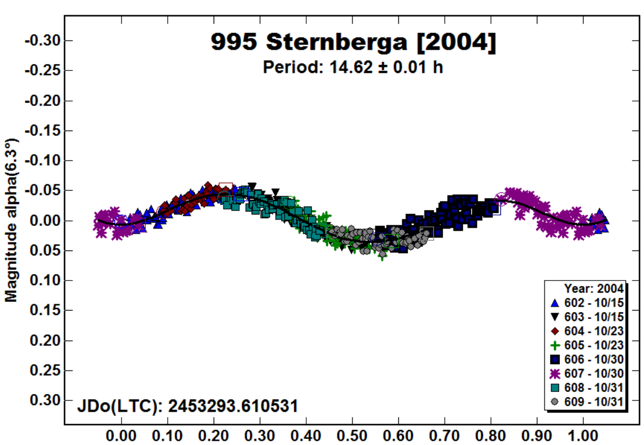
995 Sternberga [2004]
Period: 14.62 ± 0.01 h
Magnitude alpha(6.3°)
Year: 2004
602 - 10/15
603 - 10/15
604 - 10/23
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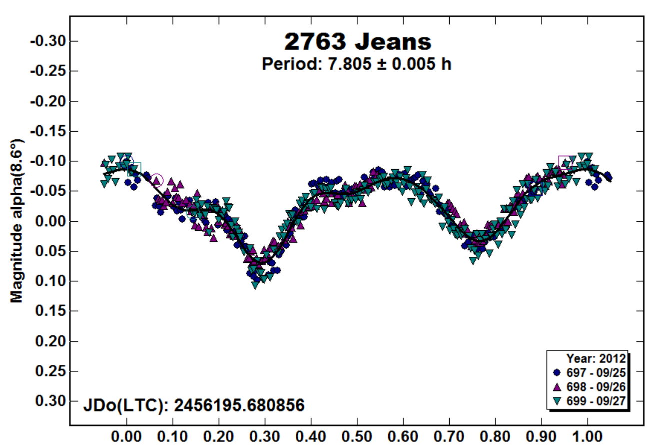
2763 Jeans
Period: 7.805 ± 0.005 h
Magnitude alpha(8.6°)
Year: 2012
697 - 09/25
698 - 09/26
699 - 09/27
JDo(LTC): 2456195.680856

ROUNDING UP THE UNUSUAL SUSPECTS

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The results of analysis of CCD photometric observations for seven Hungaria asteroids are reported: 3873 Roddy, 7187 Isobe, (7247) 1991 TD1, 8348 Bhattacharyya, (25332) 1999 KK6, (30311) 2000 JS10, and (67175) 2000 BA19. Of this group, 3873 Roddy and 7187 Isobe, are considered to be new discoveries of small binary (D_P < 10 km) systems. This brings the total of known Hungaria binaries to 16. (7247) 1991 TD1 also resembles a binary object, but there are concerns with this conclusion because the second period is almost commensurate with an Earth day. It is a low-amplitude object with ambiguous period solutions. 8348 Bhattacharyya may be an example of an asteroid with a spin axis nearly in the ecliptic plane, which results in low amplitude lightcurves that are difficult to analyze. (25332) 1999 KK6 showed some evidence of a binary nature but it is more likely due to a trait of Fourier analysis. (30311) 2000 JS10 is another example where the Fourier analysis may have been led astray. (67175) 2000 BA19 also shows signs of a secondary period, but of 275 h. This would make it one of small number of objects that show two periods, one of ~2.2-2.5 h, and the other of 200 h or more.

CCD photometric observations of seven asteroids were made at the Palmer Divide Observatory (PDO) from 2012 June to September. The lightcurves for each presented some unusual features that gave reason to believe that, in five cases, the object might be binary. For two of those, the evidence is sufficient to consider them new binary discoveries. The strength of the evidence for the others is not, however, to the point where one can make any claims with certainty. At the very least, these candidates warrant high-precision photometry at future observations to confirm, refine, or refute the results given here. The other cases presented some challenges during analysis that make them good case studies for those doing asteroid photometry and period analysis.

Background

See the introduction in Warner (2010) for a discussion of equipment used in 2012, analysis software and methods, and overview of the lightcurve plot scaling. The "Reduced Magnitude" in the plots is Johnson V or Cousins R (indicated in the Y-axis title) corrected to unity distance by applying –5*log (rΔ) with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using G = 0.15 unless otherwise stated.

For the sake of brevity in the following discussions on specific asteroids, only some of the previously reported results are referenced. For a more complete listing, the reader is referred to the asteroid lightcurve database (LCDB, Warner *et al.*, 2009). The on-line version allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files, including the references with bibcodes, is also available for download at *http://www.minorplanet.info/lightcurvedatabase.html*. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

Individual Asteroids

3873 Roddy. This Hungaria asteroid was previously observed at PDO in 2005 (Warner, 2006), 2007 (Warner, 2008a), 2009 (Warner, 2009), and 2010 (Warner, 2011b). The results from each data set was a period of ~2.479 h. Data from the 2007 apparition gave unconfirmed indications that the asteroid was binary and the orbital period was about 48 h. This was based, however, on only two nights where either an eclipse or occultation was supposedly seen. The phase angle bisector longitude (L_{PAB}) at the time was about 356°. The L_{PAB} during the 2012 apparition was similar, ~322°, and so the asteroid was followed for a greater amount of time than usual to see if evidence of a binary could be found.

Analysis of the 2012 data set of more than 400 observations found good indications of a second period of 19.24 ± 0.02 h. On the

#	Name	mm/dd/(20)yy	Pts	Phase	L_{PAB}	B_{PAB}	Period		P.E.	Amp	A.E.
3873	Roddy	08/09-09/13/07	472	24.1,18.1	356	31	2.47900	P	0.00006	0.11	0.01
3873	Roddy	08/13-09/16/12	405	17.7,22.1	322	31	2.4797	P	0.0001	0.08	0.01
7187	Isobe	08/29-09/02/04	289	18.0,17.1	353	19	4.247	P	0.002	0.18	0.02
7187	Isobe	11/11-12/16/07	258	27.5,18.6	83	28	4.2431	P	0.0001	0.15	0.01
7187	Isobe	02/12-03/02/11	234	6.1,15.0	149	-10	4.2437	P	0.0003	0.13	0.01
7187	Isobe	08/26-09/21/12	507	8.0,20.0	333	13	4.2427	P	0.0002	0.09	0.01
7247	1991 TD1	09/14-09/22/12	311	18.7,21.1	336	17	6.3515	P	0.0009	0.17	0.01
8348	Bhattacharyya	09/05-10/03/07	413	22.7,21.2*	3	28	19.60		0.01	0.06	0.01
8348	Bhattacharyya	08/26-09/10/12	337	14.9,18.7	333	21	19.58/39.83		0.03/0.06	0.10	0.01
25332	1999 KK6	10/04-10/20/07	235	14.3,14.0*	14	16	2.453/4.906		0.001	0.08	0.01
25332	1999 KK6	07/18-08/25/12	206	26.0,26.1*	315	36	2.4139	P	0.0002	0.06	0.01
30311	2000 JS10	09/14-09/21/12	395	13.7,13.9	352	25	2.267		0.001	0.06	0.01
67175	2000 BA19	07/21-09/10/12	239	18.1,23.4*	320	21	2.7157	P	0.0001	0.07	0.01

Table I. Observing circumstances. The phase angle (α) is given at the start and end of each date range. An asterisk (*) indicates the phase angle reached a minimum during the period and started to increase. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude. A 'P' in the period column means the value is for the presume primary in a binary system. See the text for details regarding the second period. If two periods are given, the solution was ambiguous, with either being about equally likely.

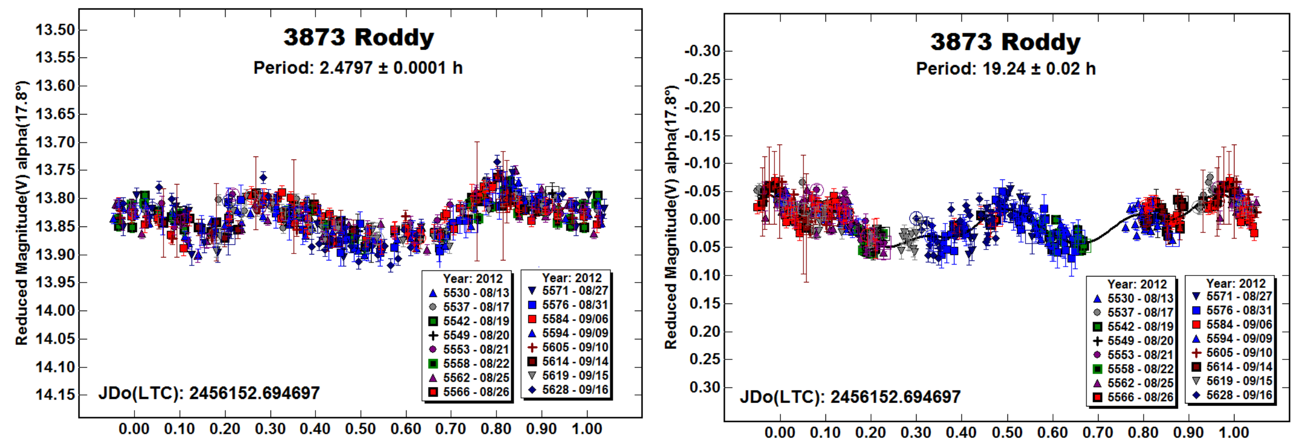

Figure 1. The lightcurves for 3873 Roddy during the 2012 apparition. The left-hand plot shows the rotation of the primary of a purported binary system. The right-hand plot shows the result after subtracting the top lightcurve.

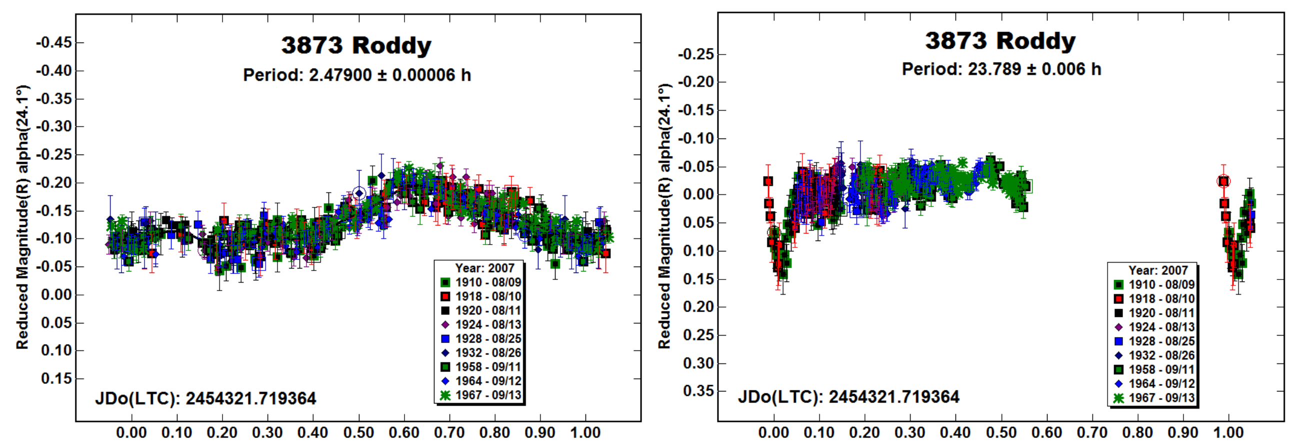

Figure 2. The lightcurves for 3873 Roddy based on data obtained in 2007.

assumption that this is a binary, the lightcurve gives evidence of a satellite with the estimated size ratio of the pair is Ds/Dp = 0.27 ± 0.02.

Using these results as a guideline, the data from 2007 were re-analyzed. Figure 2 shows the results. This gave P_1 = 2.47900 ± 0.00006 h, in good agreement with the period found from the 2012 analysis. However, the data could not be fit to a period of about 19.3 h. Instead, the only reasonable solution was one 23.8 h. An additional concern is that the two "events" in the 2007 data are at the beginning of the evening runs. There do not appear to be any issues with the early data of those sessions, e.g., the comp star averages don't show ill behavior and a test star in the field near the asteroid shows a "flat curve." Still, the 2007 data should be viewed with at least some suspicion.

From the five apparitions observed so far, the short period seems to be well-defined and in no doubt. Obviously, the two secondary periods presented here cannot both be right. Another curiosity is the significant difference in the shape of the "primary" period lightcurve between the two apparitions even though the viewing aspects and phase angles were fairly similar. High-quality observations are strongly encouraged in the future.

7178 Isobe. Previous apparitions worked at PDO include 2004, 2007, and 2011. The period was first reported to be 2.440 h (Warner, 2005a) or 2.58 h (Warner, 2008b) but follow up analysis of all data sets after the 2011 apparition (Warner, 2011c) determined that a better solution was 4.243 h. The observations in 2012 showed indications of a satellite, leading to a somewhat extended campaign in search of convincing evidence. On the assumption of there being a satellite, Figure 3, using the data from 2012, shows the primary rotation lightcurve with a period of 4.2427 ± 0.0002 h, amplitude 0.09 ± 0.01 mag (top) and two possible solutions for the secondary period. Of the two, the longer solution, P = 33.22 ± 0.04 h, seems a little more probable since the "events" are about equally spaced in the overall curve, i.e., about 0.5 rotation apart. If real, the satellite is probably tidally-locked to its orbital period. Based on the analysis of the 2012 data, the earlier data sets were analyzed anew.

The 2004 apparition (Figure 4, L_{PAB} ~353°) also showed signs of a satellite. The primary period was 4.246 ± 0.001 h. The two secondary periods were 16.34 ± 0.03 h and 32.66 ± 0.07 h. Given the noisy data, on the order of ± 0.1 mag, and smaller data, set the agreement with the 2012 results is reasonably good.

The results from 2007 (Figure 5, L_{PAB} ~83°) and 2011 (Figure 6, L_{PAB} ~149°) are in good agreement with 2012 for the primary period. The two longer periods are somewhat shorter than found in 2012. This could be due to a lack of coverage, both overall and of multiple instances of supposed events.

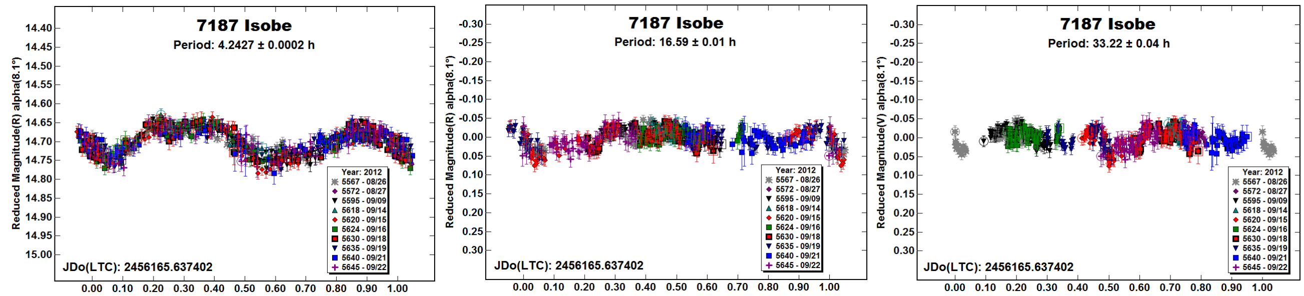

Figure 3. 7187 Isobe lightcurves from 2012. The left-hand plot is the rotation of the purported primary. The middle plot shows the shorter possible solution for the satellite, which is probably tidally-locked to its orbital period. The right-hand plot shows the longer solution with a possible near total eclipse around 0.55 rotation phase.

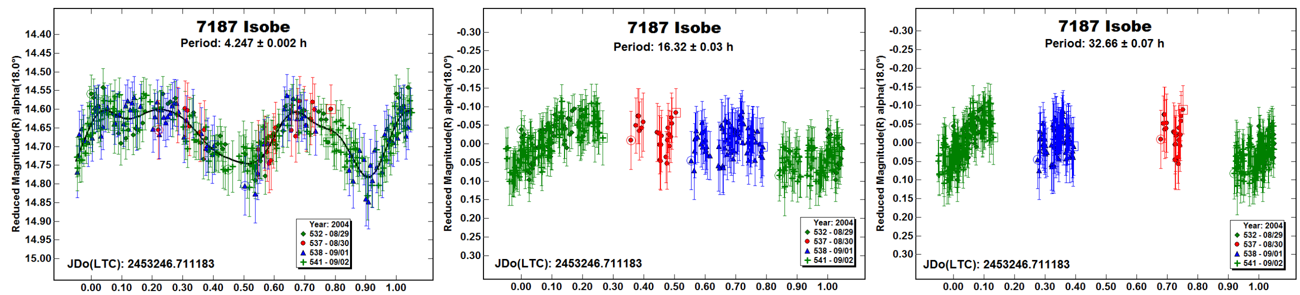

Figure 4. 7187 Isobe lightcurves from 2004. The data were on the order of ± 0.1 mag and the coverage of the longer secondary period not as complete as in other apparitions. This may have led to the slight disagreement with results from the other apparitions.

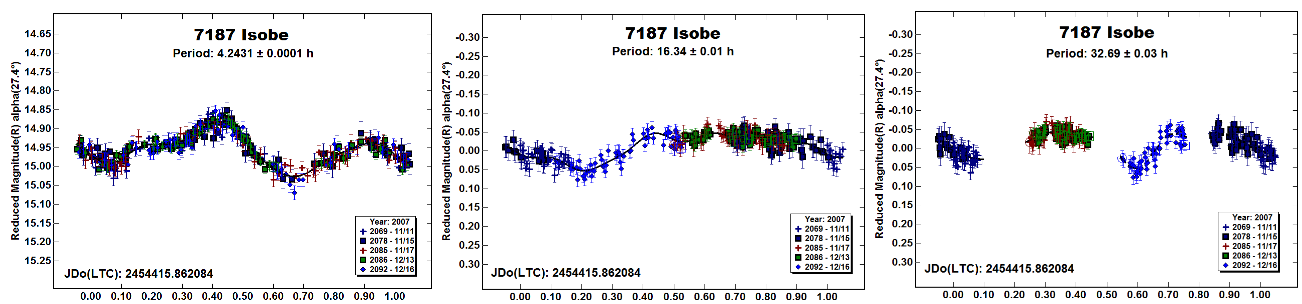

Figure 5. 7187 Isobe lightcurves from 2007. This longer second period lightcurve shows what is commonly attributed to a tidally-locked satellite with mutual events (about 0.1 and 0.6 rotation phase).

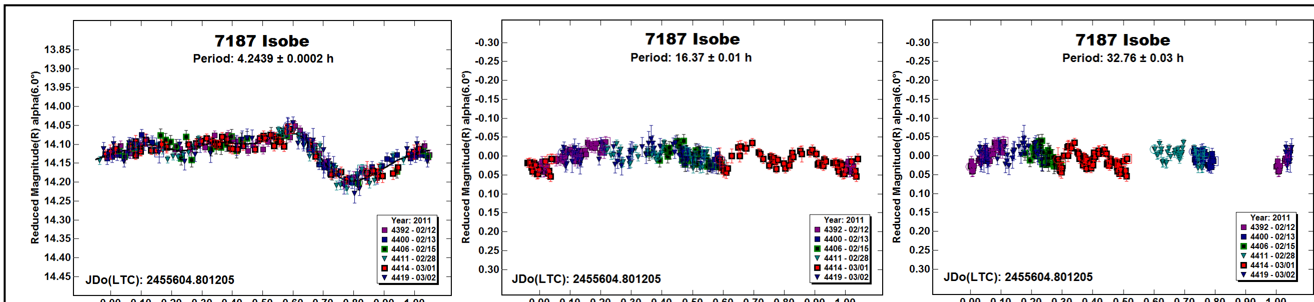

Figure 6. 7187 Isobe lightcurves from 2011.

Overall, it is likely that this asteroid is a binary. Given the apparent observation of events at varying values of L_{PAB}, the obliquity of the spin axis of the primary is somewhat low and so high-quality observations at future apparitions have a good chance of helping confirm the nature of the asteroid.

(7247) 1991 TD1. This was the first apparition of observations at PDO for this Hungaria asteroid. No entries for it were found in the LCDB. Since the untreated lightcurve seemed to have some minor deviations, a search for a second period was made. The result was a very weak solution of 16.032 h. However, there are many concerns with this solution, the primary one being that it is almost exactly commensurate with an Earth day and so observations every other night cover almost the exact same part of the lightcurve. The alternate sides of the curve have the same shape, meaning that a period of 8 h or 12 h would fit about as well (Harris, private

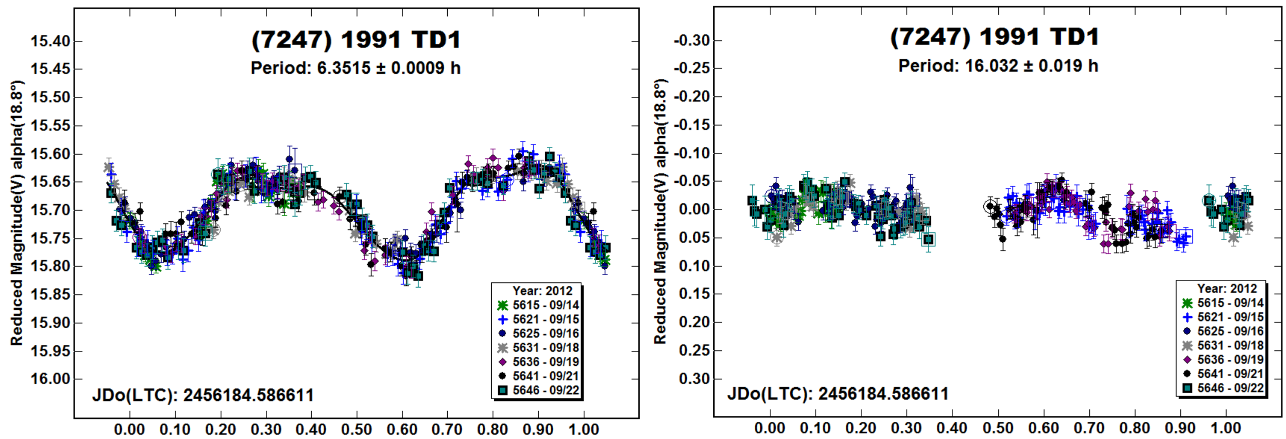

Figure 7. The lightcurves for (7247) 1991 TD1. Given the amplitude that is approaching 0.2 mag, a bimodal lightcurve for the "primary" is preferred, though still not absolute. See the text for a discussion of the secondary lightcurve. In short, the evidence for the asteroid being binary is far from sufficient.

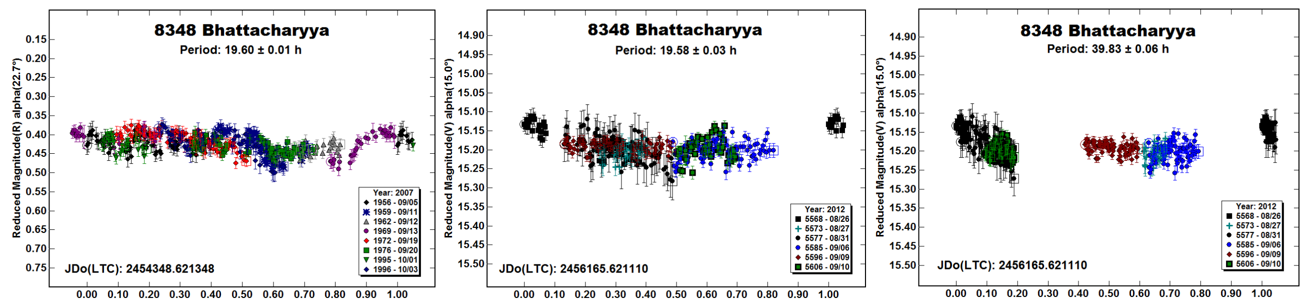

Figure 8. The lightcurves for 8348 Bhattacharyya. At left is a plot of the 2007 data with a period of 19.60 h. The middle plot is of the 2012 data with a period of 19.58 h. The right-hand plot attempted to plot the 2012 data to a period near the 38.6 h period reported in Warner, 2008a.

communications). These anomalies might be systematic errors tied to the location in the sky, the flat field, or other errors. However, a field star of about the same brightness and near the asteroid was measured and it did not show the variations found in the secondary lightcurve of the asteroid. At best, this can be said to be a good candidate for future follow-up.

8348 Bhattacharyya. This Hungaria was worked at PDO in 2007 (Warner, 2008a) under the designation 1988 BX. At that time, a period of 38.6 h with an amplitude of 0.1 mag was reported. It was given a U = 1 (probably wrong) rating in the LCDB. Data were obtained in 2012 August and September with the hope of finding a more definitive rotation period. Fortune was not kind. The L_{PAB} in 2007 was about 3° while in 2012 it was about 333°. Since the longitudes differed by only 30 degrees, it was likely that the amplitude of the lightcurve would be similar in both case, and it was. The low amplitude could mean that the object is not very elongated, but that conclusion awaits observations at another apparition, when the L_{PAB} is near about 90° or 270°.

The 2012 data fit a period of 19.58 h better than one of 39.8 h, which was found when trying to duplicate the results from the 2007 apparition. Figure 8 shows the 2007 data forced to a period in the range of 19-21 h as well as the 2012 data phased to 19.58 h and 39.8 h. These support the shorter period but are hardly conclusive. Observations at future apparitions, especially at significantly different longitudes, are encouraged.

(25332) 1999 KK6. The 2012 apparition was the second one at which this Hungaria was observed at PDO. The first time was in 2007 (Warner, 2008b) when a period of 2.4531 h was reported but also that one of 4.9062 h was possible (see Figure 9). It's of some interest that a period search of the 2007 data from 2-5 hours using steps of 0.01 h shows almost no trace of the 2.45 h solution while one at 4.9 h stands out, but not nearly as much as in Figure 10. This shows the need to assure that the step sizes in a Fourier analysis don't allow "skipping over" what may the true solution.

The revised analysis of the 2007 data set was prompted by hints of a secondary period in the 2012 data, initial analysis of which found a period of about 4.8 h, but the fit was not particularly good, thus the attempts to find a second period. Those lead to a period of 2.414 h as well as two possible solutions for a second period (Figure 10), 16.18 h or 29.13 h, or almost exactly a 9:5 ratio. Of the two secondary solutions, the shorter one shows something that might be expected of a tidally-locked satellite, i.e., the 0.07 mag broad bowing of the curve, although is asymmetric in shape. Attempts to find a solution near the double period were not productive.

All this was done with 6^{th} order fits in the Fourier analysis. However, when 4^{th} order fits were tried, while the primary period did not change significantly, the secondary periods did. More important, the new values were not commensurate with the original ones. As demonstrated by Harris *et al.* (2012), such changes are often indicative that the analysis is locking on to random noise in the data and the resulting periods cannot be trusted. For all the ways that the secondary plots from the 2012 data might seem plausible, they are more likely false and merely serve to "dust the

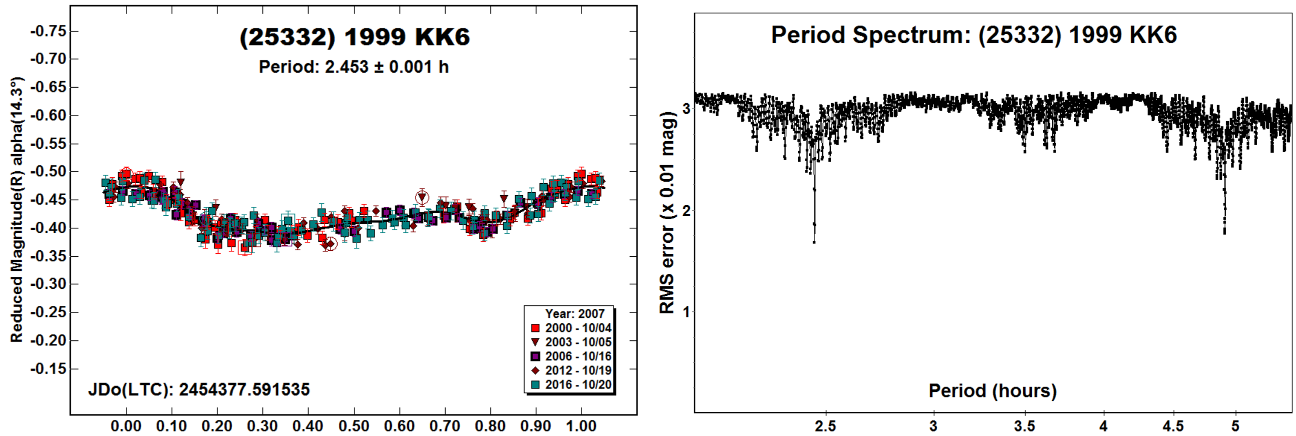

Figure 9. The lightcurve for (25332) 1999 KK6 in 2007. There was no evidence of a satellite found. The period spectrum (right) shows a strong preference for a solution of 2.453 h, which does not fit with the 2012 data.

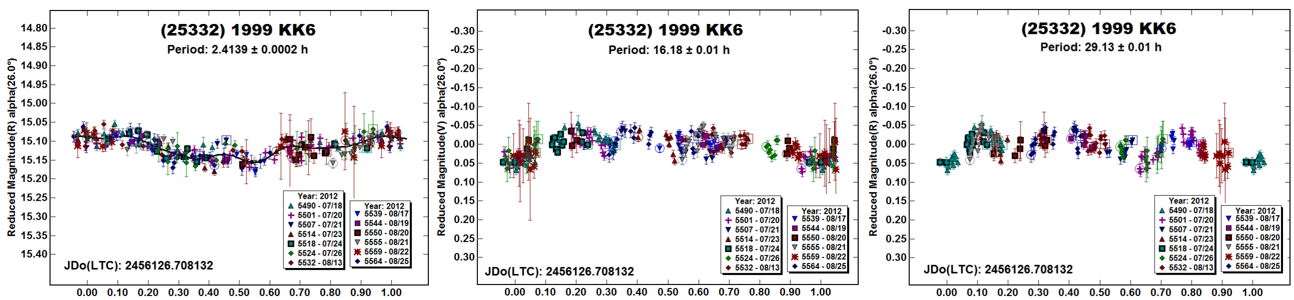

Figure 10. The lightcurves for (25332) 1999 KK6 in 2012 when using 4th order Fourier fits. If 6th order fits were used, the long period solutions changed to different, non-commensurate values, indicating that the analysis was finding false periods within the noise of the data. This makes this asteroid an unlikely binary candidate.

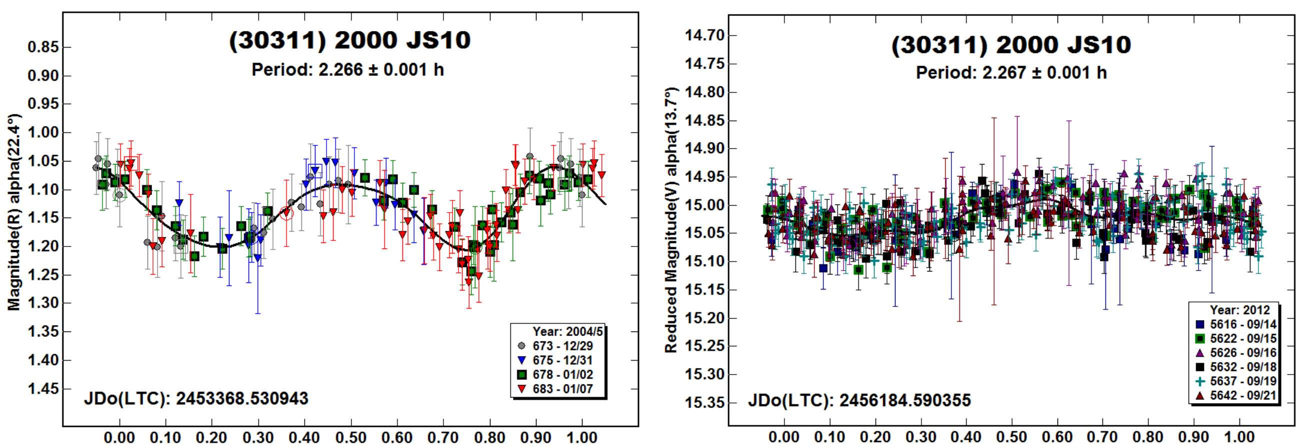

Figure 11. The lightcurve for (25332) 1999 KK6 in 2007. There was no evidence of a satellite found. The period spectrum (right) shows a strong preference for a solution of 2.453 h, which does not fit with the 2012 data.

dirt off" the single period curve. This is all the more likely given the sometimes noisy and sparse data due to the asteroid moving through crowded star fields.

Despite the likely probability that this is a single body, it should remain a "target of interest" at future apparitions.

(30311) 2000 JS10. Previous observations and analysis at PDO (Warner, 2005b) found a period of 2.266 h and amplitude 0.15 mag. These make the asteroid a good binary candidate and, if for no other reason, it was observed in 2012 to provide additional data for spin axis modeling. Figure 11 shows the lightcurves from 2004 and 2012. A check of the 2004 data found no significant traces of a secondary period. With amplitude of 0.15 mag, the odds of a bimodal solution were favored over that of a monomodal. This served as a guide, but not hard rule, when analyzing the 2012 data.

Analysis of the 2012 data found a period in almost perfect agreement with the earlier result, but with a lower amplitude of only 0.06 mag. This favors having the spin axis near the L_{PAB} at that time, i.e., about 350°, or its +180° solution of 170°.

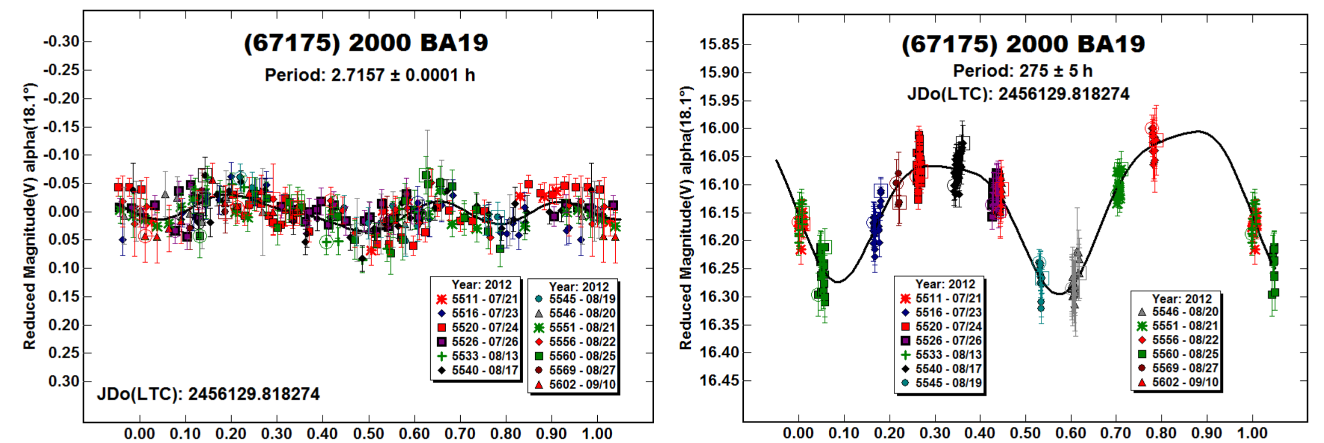

Figure 12. The lightcurve for (67175) 2000 BA19. The left-hand plot shows what appears to be a short period component superimposed on the long period lightcurve. Calibrated data, i.e., on at least an internal standard, are required to handle this type of object.

An attempt was made to look for a secondary period in the 2012 data, despite it being noisy due to the asteroid moving through crowded star fields. A weak solution was found at about 13.7 h. However, this is very close to an integral multiple of the 2.267 h period and, as outlined in the discussion on (25332) 1999 KK6, is likely the result of the Fourier analysis locking onto noise in the data. Subtracting that faint noise would, naturally, appear to make the lightcurve for the shorter solution appear better.

Since this is a binary candidate, observations are encouraged at future apparitions but the analysis should not be influenced by these results. Independent confirmation, not a self-fulfilling conclusion, is what's required.

(67175) 2000 BA19. This is the first apparition at which this Hungaria was observed at PDO. No entries could be found in the LCDB. The lightcurve with a short period of 2.7157 h and amplitude of about 0.07 mag, is typical for a primary in a small binary system. However, what is not typical is the apparent large amplitude (0.29 mag) secondary lightcurve with a period of 275 h. At least two other asteroids have shown similar characteristics, 8026 Johnmckay (P_1: 2.2981 h, P_2: 372 h; Warner, 2011a) and (218144) 2002 RL66 (P_1: 2.49 h, P_2: 588 h; Warner *et al.*, 2010).

Jacobson and Scheeres (2012, and references therein) have explored the theoretical evolution of asynchronous binaries and found that one possible track, where the primary is synchronous, the secondary asynchronous, and the system has a high mass ratio (> ~0.2), may account for these three unusual cases. Given the long secondary periods, the chances of recording mutual events with standard photometry, even if deep enough, are exceedingly poor. Therefore, confirmation of these objects may be a long time coming, if ever at all. One hope is that Adaptive Optics (AO) or speckle photometry might be able to isolate the two bodies. The author has been in contact with Jacobson and there are plans to try to obtain AO observations of these candidates when/if the opportunity allows.

Conclusion

Analysis of data obtained at PDO in 2012 and reanalysis of earlier observations indicates that two asteroids, 3783 Roddy and 7187 Isobe, are probably binary asteroids. Three other objects showed some signs of a satellite but these are better attributed to traits in Fourier analysis giving false leads. There is an expression, "When you hear hoof beats, don't think zebras," meaning that one should always keep the rule of Occam's Razor in mind: the simplest answer is usually the right one. This doesn't mean that one shouldn't investigate when there are even just faint hoof beats, but he should have an open mind and a good dose of skepticism when doing so.

The case of (67175) 2000 BA19, where it may be a member of a rare form of binary asteroids, provides some cautionary lessons. The first is that data should always be placed on at least an internal system with as stable a zero point as possible. Otherwise, the temptation can be (as seen in the past) to mask long period variations by forcing the zero points of individual sessions on the assumption of a shorter period.

There are many ways to achieve this goal. Even one of ± 0.05 mag stability can go a long way towards unveiling new discoveries. In some cases, however, a level of 0.01-0.02 mag is required. This is especially true when trying to coax evidence of a satellite from a lightcurve. So far, deviations of 0.05 mag are about the current limit for reliably detecting mutual events. It may not be possible to go much lower than this without finding too many "zebras."

The second important lesson is that it is dangerous to presume. When a long period asteroid is found, there is a temptation to minimize the number of data points obtained each night so that other objects can be observed. As the number of data points goes down, the need for well-calibrated data goes up – significantly. Small errors in measurements can lead to large errors in the final solution. More to the point, however, is that getting too few data points may hide a short period riding on top of the long period roller coaster. As a result, the additional evidence to confirm objects such as 2000 BA19 may be forever lost. Balancing the two needs is one of the more difficult aspects of asteroid photometry.

Acknowledgements

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FAST ROTATION OF THE NEA 2012 TC4 INDICATES A MONOLITHIC STRUCTURE

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In 2012 October the asteroid 2012 TC4 made a near-Earth pass at a distance of 15.5 Earth-radii. This close approach was used for photometric observations to derive its rotation period of 12.24 ± 0.06 min and lightcurve amplitude of 0.9 ± 0.1 mag. These values indicate a monolithic structure for an elongated body.

Near-Earth asteroids (NEAs) that graze the Earth at distances of a few Earth-radii are a potential source of concern, but also present an opportunity to study small-sized asteroids in our immediate neighborhood. During a short window of opportunity, astronomers can measure the spectrum and brightness variation, from which the composition, size, rotation period, and shape can be interpreted.

On 2012 October 12, the asteroid 2012 TC4 passed near the Earth at a distance of ~10^5 km (15.5 Earth-radii). The asteroid, having a small orbital inclination, crossed the Earth’s orbit inward, towards the Sun. As a result, it became unobservable after the pass since its night hemisphere was facing the Earth. Due to its proximity, its declination, velocity on the sky, and magnitude quickly changed during the pass (between 0° to –40° and back to 0°, 0.03 to 14 arcsec/s, V ~ 18 to 14 and back to 26, respectively). Therefore, in order to get enough counts without smearing the signal of the

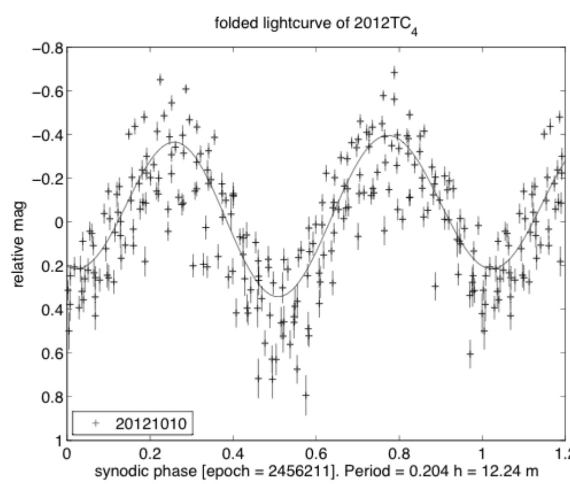

Figure 1. The lightcurve for 2012 TC4 phased to a period 12.24 min.

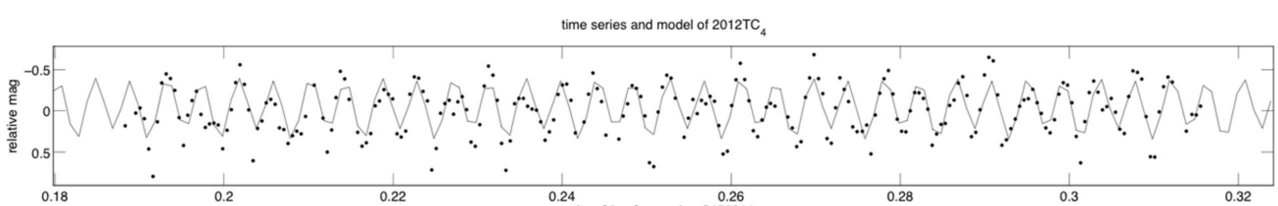

Figure 2. Raw time series plot of 2012 TC4 data.

asteroid, it was observed before closest approach at a magnitude of 16.7 and sky velocity of 0.3 arcsec/s using 15-s exposures.

The observations took place on 2012 October 10, from 16:30-19:30 UT, 36 hours before closest approach at a geocentric distance of ~850,000 km (~134 Earth-radii) and phase angle of 28 degrees. 235 images were recorded. Observations were performed using the 0.46-m Centurion telescope (Brosch *et al.*, 2008) of the Wise Observatory (MPC 097). The telescope was used with an SBIG STL-6303E CCD at the *f*/2.8 prime focus. This CCD covers a wide field of view of 75x50 arcmin with 3072x2048 pixels, with each pixel subtending 1.47 arcsec, unbinned. Observations were performed in "white light", i.e., with no filters (clear). The asteroid was observed while crossing a single field, thus the same comparison stars were used to calibrate the images.

The images were reduced in a standard way. IRAF's *phot* function was used for the photometric measurements. After measuring, the photometric values were calibrated to a differential magnitude level using ~200 local comparison stars. The brightness of these stars remained constant to ± 0.02 mag. Analysis for the lightcurve period and amplitude was done by Fourier series analysis (Harris and Lupishko, 1989). See Polishook and Brosch (2009) for complete description about reduction, measurements, calibration and analysis.

The periodic variation of 2012 TC4 is easily visible in its lightcurve. A rotation period of 12.24 ± 0.06 min (Fig. 1) best matches the variations (with 1-sigma of uncertainty). Since 2012 TC4 was observed during 3 hours, ~14.5 cycles are visible on the lightcurve (Fig. 2). The amplitude is 0.9 ± 0.1 mag. Under the assumption of a triaxial shape ($a \geq b \geq c$), the lightcurve amplitude corresponds to minimal a/b axial ratios of 2.3 ± 0.2, or an elongated shape.

Assuming an albedo of 0.15 and the absolute magnitude provided by the MPC website (26.7), the effective diameter of 2012 TC4 is 15 meters. Choosing conservative values for the boundaries of these parameters (albedo: 0.05 to 0.4; absolute magnitude: ± 0.5 mag) in order to estimate the uncertainty of the diameter, the effective diameter of 2012 TC4 is 7 to 34 meters. This small diameter, in addition to the elongated shape and fast rotation of the body, supports the notion that 2012 TC4 is not a "rubble pile" asteroid but rather it has a monolithic structure; otherwise it would have been disintegrated (Richardson *et al.* 1998).

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PHOTOMETRIC OBSERVATION OF 3024 HAINAN, 3920 AUBIGNAN, AND 5951 ALICEMONET

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Three minor planets were measured photometrically between 2012 September 4 and 21 using the SARA (Southeastern Association for Research in Astronomy) South telescope, located in Cerro Tololo Inter-American Observatory. The following synodic periods were found: 3024 Hainan, P = 11.785 ± 0.005 h; 3920 Aubignan, P = 4.4762 ± 0.0005 h; and 5951 Alicemonet, P = 3.8871 ± 0.0005 h.

All observational data reported here were obtained using the remotely-operated 0.61-m SARA South telescope located at the Cerro Tololo Inter-American Observatory in Chile. The telescope has an effective focal ratio of f/13.5. Coupled to a QSI 683s CCD camera, this resulted in a resolution of 0.27 arcsec/pixel (binned 2×2) and field of view (FOV) = 7.51×5.70 arcminutes. An SDSS r filter was used when taking images. The camera temperatures were set at –25°C. Image acquisition was done with *MaxIm DL*. All images were reduced with master bias, dark, and flat frames. All calibration frames were created using *IDL*. Period analysis was performed using *MPO Canopus,* which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989). The asteroids were selected from the list of asteroid photometry opportunities published on the Collaborative Asteroid Lightcurve Link (CALL) website (Warner *et al.*, 2008).

<u>3024 Hainan.</u> This asteroid was discovered on 1981 Oct 23 by Purple Mountain Observatory in Nanjing, China. We could find no previously reported period. It was observed from 2012 Sep 8 to 21. We obtained a period *P* = 11.785 ± 0.005 h and an amplitude *A* = 0.10 ± 0.03 mag.

<u>3920 Aubignan.</u> Data were collected on the nights of 2012 Sep. 4, 11, 12, and 25. A synodic period of 4.4762 ± 0.0005 h and an amplitude of 1.00 ± 0.01 mag were determined. No previously published results were found.

<u>5951 Alicemonet.</u> Data were collected on the nights of 2012 Sep 5, 11, and 25. A synodic period of *P* = 3.8871 ± 0.0005 h and an amplitude of 0.46 ± 0.02 mag were determined. No previously published results were found.

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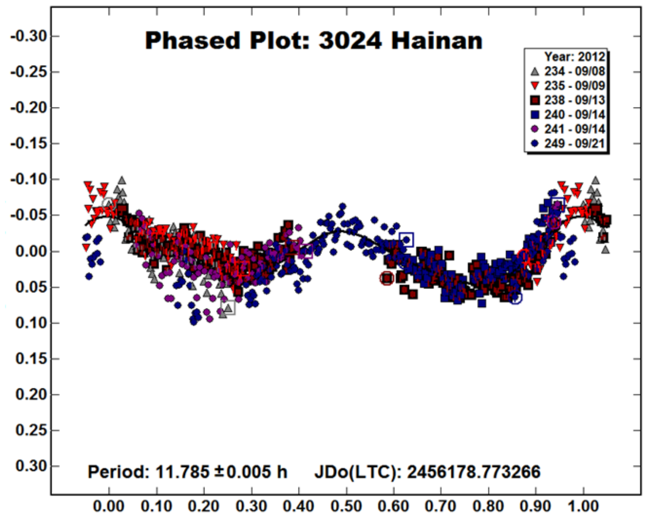

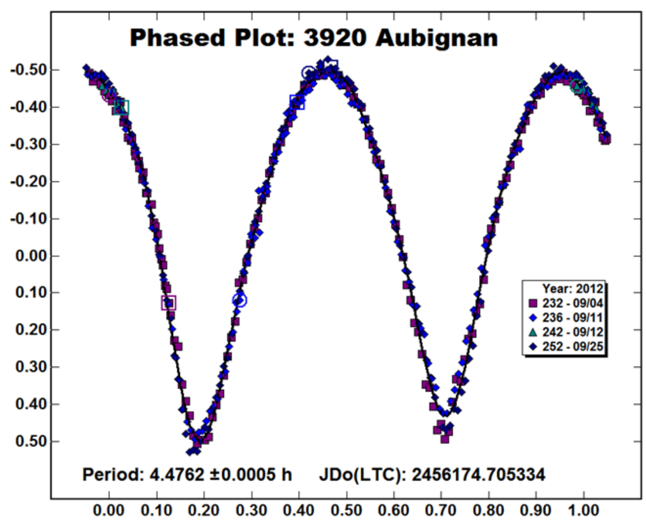

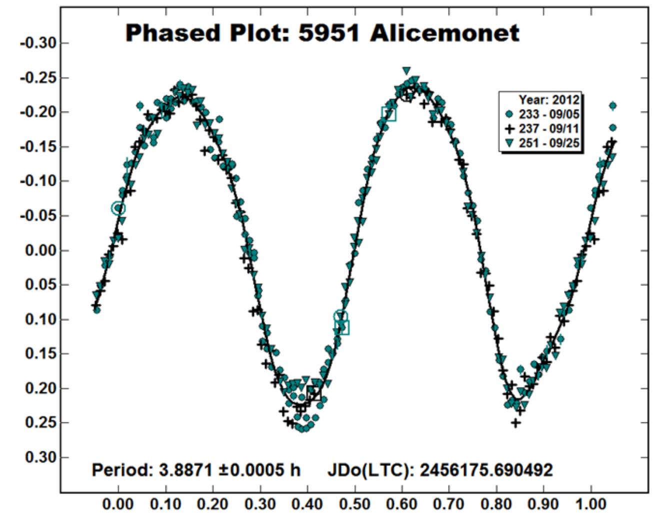

LIGHTCURVE PHOTOMETRY OF NEA 2012 TV

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Photometric observations of near-Earth asteroid 2012 TV were made during the object's close approach to Earth on 2012 October 06. Analysis of the resulting data found a synodic period P = 0.0525 ± 0.0001 h with an amplitude A = 0.57 ± 0.04 mag.

The Apollo near-Earth asteroid (NEA) 2012 TV was discovered by Tenagra II Observatory on 2012 October 05. For this asteroid the JPL Small-Body Database Browser reported an absolute magnitude H = 25.2, with an estimated diameter from 24 to 54 meters, respectively for medium and low albedo object type.

The asteroid was observed remotely from the iTelescope network near Mayhill, NM (MPC Code H06) on 2012, October 06.3 and at Balzaretto Observatory (MPC Code A81) on 2012, October 06.8. Both observing sessions are just one day before its very close approach to Earth on the 2012, October 07. The equipment used for observations is reported in Table I.. A total of 103 unfiltered images were acquired by the two observatories over a time span of 39 minutes, with exposures of 15 and 6 seconds respectively. All images were calibrated with dark and flat-field frames. Differential photometry and period analysis was done using *MPO Canopus* (Warner, 2010) at Balzaretto Observatory. The derived synodic period was P = 0.0525 ± 0.0001 h (Fig. 1, 2), or equivalently 3.15 minutes, with a amplitude of A = 0.57 ± 0.04 mag.

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Obs	Telescope	CCD	FOV (arc-minutes)	Scale (arcsec/ pixel)
H06	0.25-m f/3.4 reflector	SBIG ST-10XME	60 x 40	1.65
A81	0.20-m f/5.6 reflector	SBIG ST7-XME	21 x 14	1.65

Table I. Equipment list.

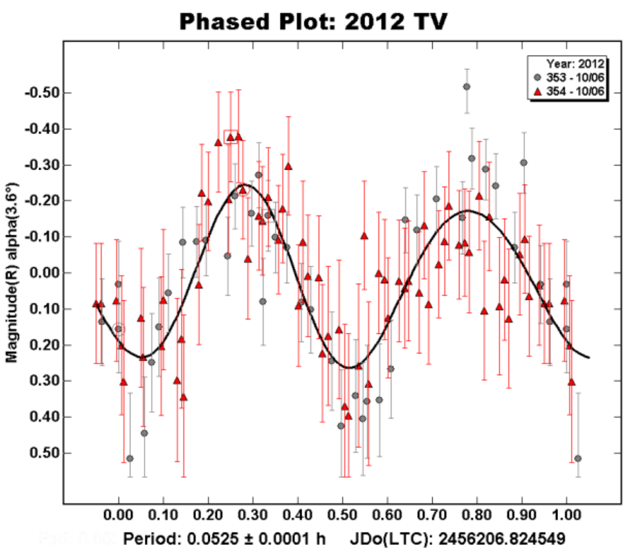

Figure 1. The light curve of NEA 2012 TV with a period of 0.0525 ± 0.0001 h and an amplitude of 0.57 ± 0.04 mag.

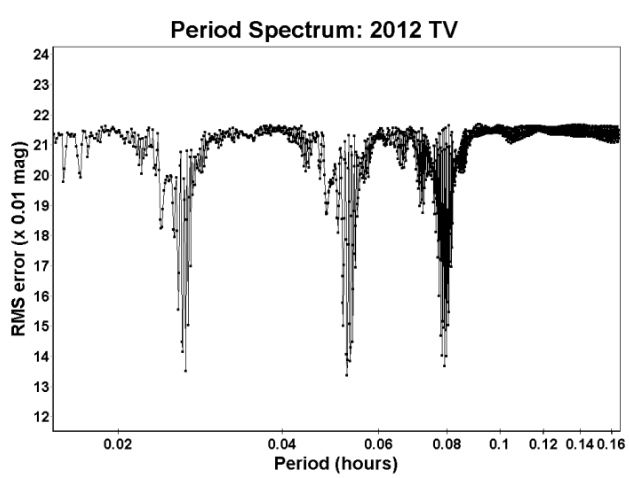

Figure 2. Period spectrum shows the main period with low RMS value and two other periods corresponding to a monomodal and trimodal solution.

EPOCH DATA IN SIDEREAL PERIOD DETERMINATION. II. COMBINING EPOCHS FROM DIFFERENT APPARITIONS

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Sidereal period determination requires establishing correct rotation counts over long time spans, which can involve ambiguities that are not necessarily correctly handled by purely statistical approaches. I describe a method to check ambiguity in counting rotations that elapse during the time spanned by an epoch data set, and to identify constraints on rotation counts and sidereal periods that can be used as inputs to spin vector analysis methods that require initial values.

Introduction

In the previous companion paper (Slivan, 2012), hereafter “Paper I”, I discussed challenges that arise when counting rotations over long intervals to determine sidereal rotation periods from lightcurves, and offered two precepts for designing a lightcurve epoch observing program. Establishing the best constraints on the sidereal period requires correctly counting the rotations between every pair of available epochs, and as is discussed in paper I, statistical methods by themselves are not a robust approach for identifying and resolving ambiguous solutions. In this second paper I describe an approach to determine what degree of ambiguity is present in counting rotations across the entire time spanned by an epoch data set, and to establish the range(s) of possible sidereal periods that are consistent with multiple apparitions of epoch data. The results of the method can be useful when judging whether the epoch data are sufficient to proceed with spin vector analyses, and they identify candidate rotation counts and sidereal periods to check when initial values are required.

The analysis combines epochs from different apparitions, therefore the change in the asteroid’s direction vector; that is, the position of the asteroid on the celestial sphere as seen by the observer, is significant and cannot be ignored. There are three contributions to the number of sidereal rotations that occur between the epochs of a particular asterocentric longitude: the integer number of half rotations elapsed, the fraction of up to ±0.5 of a rotation “induced” by the change in the direction vector, and finally a fraction of a rotation that depends on the change in viewing aspect angle with respect to the asteroid's spin vector. The statistical least-squares fitting approaches that make use of this last contribution for spin vector determination, by themselves are not well-suited to also determining the rotation counts because of the aliasing issues involved. Instead, a more robust approach for identifying the correct sidereal period is to first eliminate as many alias periods as possible by constraining rotation counts separately, including the fractional rotation induced by the change in the direction vector, but neglecting the contribution due to the change in polar aspect angle.

As introduced in Paper I, the uncertainty notation σ_{99} represents a confidence interval of “something like 99%.” In the context of checking alias periods, the motivation for using an interval larger than the customary one-sigma 68% is to reduce the chance of excluding the correct result.

Method

The method analyzes a set of epochs t_i and their uncertainties $\sigma_{99}(t_i)$, that for a main belt object includes generally one epoch per apparition. A time interval Δt and uncertainty $\sigma_{99}(\Delta t)$ can be calculated from each possible pairing of epochs from different apparitions:

$$\Delta t = t_j - t_i \quad (i < j) \qquad \text{(Eq. 1)}$$

$$\sigma_{99}(\Delta t) = \sigma_{99}(t_j) + \sigma_{99}(t_i) \qquad \text{(Eq. 2)}$$

Calculating the intervals between epochs in this way makes the assumption that both epochs of each pair correspond to the same rotational phase of the asteroid, an assumption which must be made with caution and which is discussed in the next section. Eq. 2 is intentionally conservative, using the full regular sum of the individual epoch errors rather than adding them quadratically.

For each such interval, the floating-point limits of the range in which the corresponding number of elapsed sidereal rotations lies are

$$n_{\text{low}} = (\Delta t - \sigma_{99}(\Delta t))/(P_{\text{syn}} + \sigma_{99}(P_{\text{syn}})) \qquad \text{(Eq. 3)}$$

$$n_{\text{high}} = (\Delta t + \sigma_{99}(\Delta t))/(P_{\text{syn}} - \sigma_{99}(P_{\text{syn}})) \qquad \text{(Eq. 4)}$$

where P_{syn} is the best synodic period and $\sigma_{99}(P_{\text{syn}})$ is its uncertainty as described in paper I.

Calculating the set of possible sidereal periods that are consistent with the time interval involves dividing the interval by each candidate number of elapsed sidereal rotations within the range given by Eqs. 3–4, but unlike a single-apparition case, the direction vector change is in general significant and we cannot assume that the divisor will be some integer number of half rotations. For the present purpose of indicating the range(s) of sidereal periods that are consistent with the available epochs, I disentangle spin vector orientation effects from the rotation counts by assuming that the spin vector aspect change is zero, as would be true if the aspect were equatorial at all apparitions. In a coördinate system of longitude L, latitude B whose equatorial plane is parallel to the orbit plane, the angular difference in direction vector longitude as seen from Earth is

$$\Delta L = L_j - L_i \qquad \text{(Eq. 5)}$$

If the orbit is near the ecliptic plane then $\Delta L \approx \Delta\lambda$ the difference in ecliptic longitudes, an approximation which should be appropriate for most main belt objects. To allow for the effect of nonzero solar phase angle on observed times of epochs, I represent the asteroid direction by the phase angle bisector (Harris et al., 1984). Formally transforming ecliptic λ, β to L, B if the orbit inclination were large would involve rotating the coördinates' pole by the angle of the inclination.

The corresponding fraction of a rotation ΔN induced by the object's changed direction vector is

$$\Delta N = (\Delta L / 360°) \bmod 0.5 \qquad \text{(Eq. 6)}$$
$$(0 \le \Delta N < 0.5)$$

The number of sidereal rotations that can occur between the epochs will be $N \pm \Delta N$, where N is some integer number of half rotations, and the algebraic sign of ΔN is related to the sense of spin: $+\Delta N$ corresponds to spin in the same sense as the orbit motion and $-\Delta N$ corresponds to spin opposite that of the orbit. The bounds on N are

$$N_{\text{low}} = 0.5\ \text{CEIL}(2n_{\text{low}} - 2\Delta N) \qquad \text{(Eq. 7)}$$

$$N_{\text{high}} = 0.5\ \text{FLOOR}(2n_{\text{high}} + 2\Delta N) \qquad \text{(Eq. 8)}$$

where CEIL(x) is the smallest integer not less than x, and FLOOR(x) is the largest integer not greater than x. The set of integer numbers of half rotations N_k possible for the time interval are the values from N_{low} to N_{high} inclusive, stepping by increments of 0.5 rotation. In some cases when the bounds calculated using Eqs. 7–8 are 0.5 rotation apart it's possible that $N_{\text{low}} > N_{\text{high}}$, in which case these bounding values should be exchanged to ensure that the correct count is retained.

For each possible count N_k the corresponding two sidereal periods $P_{\text{sid},k}$ (only one period if $\Delta N = 0$) are

$$P_{\text{sid},k} = \Delta t/(N_k \pm \Delta N) \qquad \text{(Eq. 9)}$$

$$\sigma_{99}(P_{\text{sid},k}) = \sigma_{99}(\Delta t)/(N_k \pm \Delta N) \qquad \text{(Eq. 10)}$$

A sidereal period range result that lies completely outside the synodic period range can be immediately rejected. Similarly, if adjacent sidereal period ranges calculated from the same epoch interval are large enough to overlap then they rule out no periods, in which case that interval can be excluded from this analysis without loss of information.

After the individual possible sidereal period ranges have been calculated for every time interval using Eqs. 9–10, the range(s) of periods $P_{\text{sid,low}}$ to $P_{\text{sid,high}}$ that are common to all of the available intervals can be identified. Using the longest time interval $(\Delta t)_{\max}$ to ultimately obtain the most precise period results, each range of shared possible periods establishes bounds on the corresponding numbers of sidereal rotations by

$$n_{\max,\text{low}} = ((\Delta t)_{\max} - \sigma_{99}((\Delta t)_{\max}))/P_{\text{sid,high}} \qquad \text{(Eq. 11)}$$

$$n_{\max,\text{high}} = ((\Delta t)_{\max} + \sigma_{99}((\Delta t)_{\max}))/P_{\text{sid,low}} \qquad \text{(Eq. 12)}$$

The value(s) of $N_k \pm \Delta N$ for $(\Delta t)_{\max}$ that are within this range yield the final possible sidereal period result(s) by Eqs. 9–10.

Discussion

A key assumption of the method is that both epochs of each pair used in Eq. 1 correspond to the same rotational phase of the asteroid: There must be a feature in both lightcurves identifiable as the epoch, and it must correspond to either the same asterocentric longitude or reflex longitudes during both apparitions. Thus the method is most easily used for elongated asteroids with low or moderate spin vector obliquities.

Appropriate estimates for the epochs' uncertainties are important because they directly affect the sizes of the allowed ranges of individual period results. The estimates will depend on the lightcurves' shapes and data quality as well as on how the epochs are determined, and can also somewhat allow for systematic shifts in case the assumption of unchanging rotation phase isn't entirely true. For the "typical" lightcurves (doubly periodic and relatively symmetric, amplitude a few tenths of a magnitude, brightness errors 0.01–0.02 mag.) from which I measured the epochs for the example in the next section, I estimated an epoch uncertainty $\sigma_{99}(t)$ of about $P/15$. In any case, the correct sidereal period result should not be very sensitive to small changes in appropriately-estimated epoch uncertainties: very small disallowed or allowed ranges of result periods should be regarded with caution, as should period results that are very close to a range boundary.

To count the sidereal rotations that occur between every pair of epochs from the shortest interval (consecutive apparitions discussed in Paper I) through the longest interval spanned by the entire epoch data set, epochs need to be available a variety of time intervals apart. Shorter intervals yield fewer ambiguous alias periods but relatively coarse individual period constraints, while longer intervals with larger rotation counts yield smaller period errors but more aliases. A sufficiently complete progression of increasingly longer intermediate time intervals will permit counting rotations across the entire data set without introducing ambiguity. If needed intermediate-length intervals are lacking then future observations can be planned during the appropriate apparitions.

An epoch data set with a suitable progression of intervals might narrow possible results to as few as a single pair of sidereal periods, one prograde and one retrograde. However, it's not unlikely that the results could also include some small number of adjacent alias solutions because of the more inclusive confidence intervals used. Insofar as the point of the method is to constrain the period as best as possible before applying a subsequent statistical approach, if the number of remaining possible periods is small then it's practical to check each one individually.

Example

To illustrate the method I present as an example an epoch data set for main-belt asteroid (1223) Neckar, for which the most precise synodic (single-apparition) period is 7.821 ± 0.001 h (Slivan et al., 2003) derived from lightcurves recorded during the 1995–1996 apparition (Michałowski et al., 2000). Table I summarizes the lightcurve epoch observations for the analysis. The data set satisfies the observing precepts in Paper I with epochs from consecutive apparitions and N_{per} = 1 (Slivan, 2012, Eq. 5) indicating an unambiguous count of rotations elapsed between them. Apparitions of Neckar occur approximately equally-spaced in time at intervals of about 15 months, providing a convenient unit for checking the relative lengths of the available time intervals between epochs. Besides the consecutive apparitions, epochs are available 2, 3, 4, 5, 6, 7, 8, 10, 11, 13, and 15 apparitions apart, a progression with plenty of information to be able to count rotations across the entire data set. The orbit inclination 3° is small and I adopt $L_i \approx \lambda_i$ to calculate ΔL in Eq. 5.

Fig. 1 summarizes the candidate sidereal periods calculated from the time intervals between each pair of epochs, using a graphical approach that is convenient for identifying range(s) of periods that are consistent with all of the intervals. Each period range (Eqs. 9 and 10) is plotted as a vertical bar extending from $P_{\text{sid},k} - \sigma_{99}(P_{\text{sid},k})$ to $P_{\text{sid},k} + \sigma_{99}(P_{\text{sid},k})$, with ranges allowed by the same time interval stacked at the same horizontal coördinate on the graph. In this example, one of the 21 possible pairings of the 7 epochs contributes no additional constraints because its ranges of individual allowed periods overlap, and it is omitted from the plot.

For the longest interval between epochs Δt(1977,1996) = 6911.0010 d and including its uncertainty, the single range of sidereal periods 7.821185 to 7.821341 h indicated in Fig. 1 is consistent with all of the available intervals and corresponds to 21206.47 to 21207.15 rotations. The three values of $N_k \pm \Delta N$ that fall within this range are given in Table II with the corresponding final possible sidereal period solutions.

During subsequent spin vector analyses I checked all three solutions, noting that the third candidate rotation count 21207.12 is only 0.03 rotation from being outside the allowed range, making it suspiciously sensitive to the uncertainties that were estimated for the epochs. Subsequent spin vector results for Neckar confirmed that the second solution is the correct count, prograde rotation with sidereal period 7.821240 ± 0.000007 h (Slivan et al., 2003).

Conclusion

I presented a method to constrain rotation counts for sidereal period determination that explicitly identifies ambiguous possible solutions. The approach is best used as part of a robust strategy to identify the correct period from among aliases by reducing the domain to be searched using statistical methods, and it can help in judging whether aliases can be resolved confidently enough to merit subsequent spin vector analyses.

In the context of spin vector analyses, correct sidereal rotation counts between all epochs are necessary but not sufficient to ensure that derived pole solutions won't be spurious, because pole results will also depend on the length of time spanned by the data (that is, the accuracy of the derived sidereal period), the number of epochs and the aspect coverage available. Exploring in detail whether epoch information in a given data set is sufficient for a given analysis method to yield creditable spin vector results is outside the scope of this paper, but I can offer at least a starting guideline based on spin vector study of about two dozen Koronis family members, whose orbits have low inclinations and apparitions about 15 months apart: When using the combination of methods described by Slivan et al. (2003) my experience has been that spin vector and sidereal period solutions based on lightcurve epochs from fewer than either 5 or 6 apparitions, depending on the object, have been spurious.

Acknowledgements

I thank Alyssa Sokol, whose epoch analysis efforts using my early draft description of the method led to an improved manuscript; she was supported by a summer fellowship from the Keck Northeast Astronomy Consortium.

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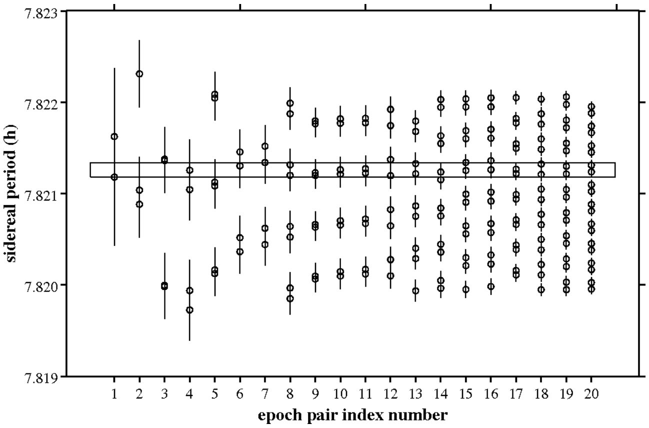

Fig. 1: Ranges of possible sidereal rotation periods of (1223) Neckar as constrained by the observations in Table I and the synodic period 7.821 ± 0.001 h. Each open circle represents a sidereal period calculated from a possible number of rotations that occurred during the time interval elapsed between the pair of observed epochs numbered on the horizontal coördinate. Length of time interval increases to the right. An uncertainty of 0.5 h was adopted for each epoch, and each vertical bar on the graph represents a range of sidereal periods that is consistent with its corresponding time interval. The thin horizontal rectangle indicates the single range of periods in this case that is consistent with all 20 time intervals.

Table I: Summary of (1223) Neckar lightcurve epoch observations 1977–1996, one epoch t per observed apparition as measured using the Fourier filtering approach described by Slivan et al. (2003). λ is ecliptic longitude of the phase angle bisector. ΔA is the number of apparition intervals elapsed since the previous epoch observed; consecutive apparitions (ΔA = 1) were observed in 1989 and 1990. Lightcurve data references: a, Tedesco (1979); b, Binzel (1987); c, Slivan and Binzel (1996); d, Michałowski et al. (2000).

t (MJD)	λ (°)	UT date	ΔA	Ref.
43187.0000	132.4	1977 Feb 13	-	a
45469.2539	230.3	1983 May 15	5	b
46885.0147	158.1	1987 Mar 31	3	c
47776.1156	328.4	1989 Sep 07	2	c
48210.1221	71.9	1990 Nov 15	1	c
49131.0887	253.0	1993 May 24	2	c
50098.0010	87.5	1996 Jan 16	2	d

Table II: Derived sidereal rotation period constraints for (1223) Neckar. $(N_k \pm \Delta N)_{max}$ are the possible numbers of sidereal rotations during the longest interval between epochs. Spin is P for prograde rotation, R for retrograde. P_{sid} is the corresponding sidereal period. The one-sigma error in each period result, estimated by adopting $\sigma_{99} \approx 2.5\sigma$, is about 0.00002 h.

$(N_k \pm \Delta N)_{max}$	Spin	P_{sid} (h)
21206.62 = 21207.0-0.38	R	7.82133
21206.88 = 21206.5+0.38	P	7.82124
21207.12 = 21207.5-0.38	R	7.82115

THE EARLY YEARS OF THE MINOR PLANETS SECTION OF THE ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

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This is a historical account of the beginning of amateur observations of asteroids in the late 1960's and 1970's, which led to the founding of the Minor Planets Section of the Association of Lunar and Planetary Observers by Richard Hodgson in 1973, and its development into the recognized source of publication of CCD lightcurves of asteroids.

Throughout the 1950's and early 1960's it was generally believed that asteroids were extremely difficult to observe. One must first plot all the stars near the predicted location, then return to the field the next day to see which one had moved. Amateurs almost universally neglected them. In 1967 I purchased a copy of Vehrenberg's Photographic Atlas of the Heavens, which shows all stars to about magnitude 13 and provides grids for finding the Epoch 1950 coordinates. I realized that if I had the ephemerides of asteroids I could overlay their predicted positions on the Vehrenberg star atlas and quickly identify the asteroid in the telescope field from its absence on the chart. The Institute for Theoretical Astronomy, Leningrad, USSR, now St. Petersburg, Russia, kindly sent me their *Ephemerides of Minor Planets for the year 1968*. In 1968 April I plotted the paths of 3 Juno and 13 Egeria, star hopped to their predicted positions with a 10 inch Celestron, and quickly identified both. I recognized from that first night that it was mandatory to look for them again on subsequent nights to confirm that they moved as predicted. Later in 1968 I observed other asteroids with this method. I published a short note in *Sky & Telescope.* Dr. J. U. Gunter was one of the readers, and we started a correspondence which lasted 17 years.

J. U. Gunter, as a hobby, started publishing and distributing at his own expense a little monthly bulletin, *"Tonight's Asteroids."* This contained finder charts for two or three bright asteroids observable in the current month. Hans Verhrenberg kindly granted permission for him to use appropriate small sections of his Atlas Stellarum charts over which to plot their paths. I certainly devised this method independently and may have been the first to use it. I do not know whether this method may have been invented independently by other observers. Following my suggestion J. U. Gunter endorsed it, and through *"Tonight's Asteroids"* it became widely known and utilized.

Dr. Gunter himself observed many of the asteroids whose charts he plotted. And he had a special talent for inspiring a whole generation of amateur astronomers, through his many personal communications as well as through anecdotes in the pages of *"Tonight's Asteroids,"* to take up visual tracking of asteroids.

In 1973 Richard Hodgson recognized that amateur observations of asteroids were becoming significant and founded a new section, the Minor Planets Section, of the Association of Lunar and Planetary Observers. Both Dr. Gunter and I accepted his invitation to join and thereby became charter members. In the early years most of the results reported were of approximate visual positions. But it became apparent that skilled amateurs could estimate asteroid magnitudes within about 0.3 even with out of field comparison with other asteroids. In the early 1970's these people found and corrected several discrepant magnitudes published in the *Ephemerides of Minor Planets.* I personally compared these amateur estimates with values found by photoelectric photometry and published in the major astronomical journals, and found them to be consistent.

As an eager high school student and perhaps the youngest charter member of the Minor Planets Section, Richard Binzel, now editor of the *Minor Planet Bulletin,* was one of those drawn by J. U. Gunter and Richard Hodgson to the visual observing of minor planets. He has kindly described his early experiences, which I quote. "As for Gunter, it was an introduction to the entire field of asteroids. It was the thrill of seeing objects moving in space, objects which were then mysterious unknown worlds. No one seemed to be studying them – what an opportunity for a young scientist! J. U. Gunter was enormously kind and encouraging to the beginner just starting out. Similarly kind was Professor Hodgson and the members of the newly founded Minor Planets Section. The MPB was a source for *actual science* about these little worlds. My, how the field has taken off since then!"

From 1973 until 1982 Richard Hodgson ran the entire show. He combined all the duties of Recorder (now called Coordinator) of the Minor Planets Section, Editor, Publisher, and Distributor of the *Minor Planet Bulletin.* When he retired from these responsibilities in 1982 Richard Binzel wished to see the *Minor Planet Bulletin* continue. He became Editor and Producer, Derald Nye became Distributor, and I accepted appointment as Recorder of the Minor Planets Section. Shortly thereafter in 1985, Bob Werner answered the call to find a separate volunteer as the Producer. All of these people have continued in their positions that now for thirty years has shepherded the growth of the *Minor Planet Bulletin* into the principal publication of asteroid lightcurves for amateur and professional observers alike.

A selection of titles of some papers in early issues of the *Minor Planet Bulletin* does much to describe the activities of the Minor Planets Section following its establishment. These do not include all the early papers; other authors might have made different choices.

Chapman, C. R. (1974). "The Impossibility of Observing Asteroid Surfaces." *MPB* **1**, 17. A contributed article at the founding of the *MPB* by one of the few professional planetary scientists studying minor planets in that era. Dr. Chapman's later career placed in him influential roles for advocating asteroid missions and in analyzing the first ever spacecraft flyby and orbiter images of asteroid surfaces.

Hodgson, R. G. (1974). "Implications of Recent Diameter and Mass Determinations of Ceres." *MPB* **1**, 24–28.

Pilcher, F. (1974). "Minor Planets at Highly Favorable Opposition in 1974." *MPB* **1**, 15–17. The author has continued this annual presentation in all subsequent years; the 2013 version is published in this issue, pp. 21–23.

Hodgson, R. G. (1974). "Minor Planet Work for Smaller Observatories." *MPB* **1**, 30–35.

Tedesco, E. F. (1974). "On the Brightness of Asteroids." *MPB* **2**, 3–9. The concept of the phase function is explained with an early linear formula and the nonlinear brightness surge near opposition is noted without quantification.

Hodgson, R. G. (1974). "The Densities of Pallas and Vesta and their Implications." *MPB* **2**, 17–20.

Welch, D., Binzel, R., and Patterson, J. (1974). "The Rotation Period of 18 Melpomene." *MPB* **2**, 20–21. This was the first report of photoelectric measurements ever made in the *MPB*, and likely the first instance in which amateurs corrected an alias rotation period published by professional astronomers (from 14h 12m to 11h 50m).

Pilcher, F. (1974). "The Line of Variation in Minor Planet Ephemerides." *MPB* **2**, 27–30. In the early 1970's a considerable number of published ephemerides were in error by as much as one degree. However the real asteroid lay close to a line extended from the predicted position, and this restricted and shortened the search necessary to find it. By early the early 1980's all sky surveys and improved computer power had corrected all of these errors.

Hodgson, R. G. (1974). "General Report of Observations by the A. L. P. O. Minor Planets Section for the Years 1973 and 1974." *MPB* **2**, 34–40. In 1976 F. Pilcher assumed responsibility for this annual report, which has appeared in the July-September issue in all subsequent years.

Meeus, J. (1975). "Least Distances of Apollo and Amor Objects to Planetary Orbits." *MPB* **3**, 1–3. Jean Meeus produced many fascinating tables of interesting orbital circumstances using what we would now consider very early generation computers.

Lagerkvist, C.-I. (1975). "Photographic Photometry of Small Asteroids." *MPB* **3**, 11–19.

Son, A. T. (1975). "Photographic Position Determination by Means of the Method of Rinia." *MPB* **3**, 39–41.

Hodgson, R. G. (1975). "An Update on Earth-Crossing Planets." *MPB* **2**, 43–44.

Porter, A. C., and Wallentine, D. (1976). "Minor Planet Rotation Studies: 1976 January-June." *MPB* **4**, 14–16.

Hodgson, R. G. (1977). "Long-Lost Planet 1936 CA ("Adonis") Recovered." *MPB* **4**, 35–36.

Harris, A. W. (1983). "Photoelectric Photometry Opportunities." *MPB* **10**, 1–3. The beginning of quarterly listings for recommended targets, which after 30 years, continues to be offered by Dr. Harris and colleagues.

Tholen, D. J. (1983). "Asteroid News Notes." *MPB* **10**, 15–16. The beginning of quarterly briefings on asteroid discoveries contributed by Dr. Tholen for nearly two decades, at which point asteroids became more main-stream news and up-to-date discovery information became more readily available via the internet.

THE MINOR PLANET OBSERVER: 40 YEARS

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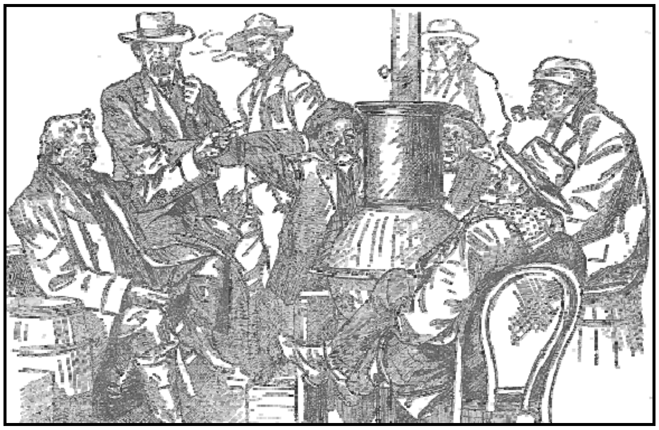
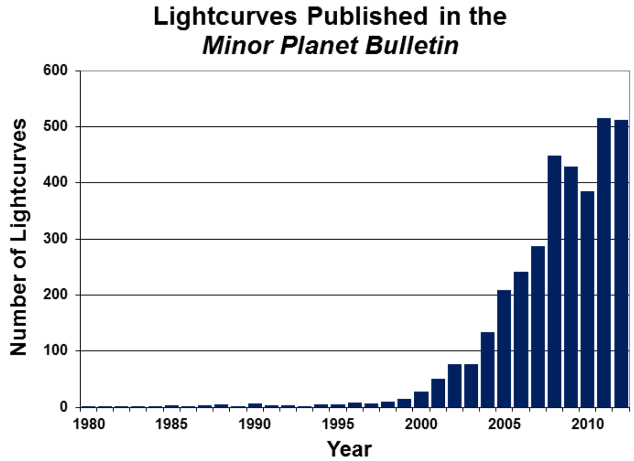
There is a bit of well-known Americana centered on the pot-belly stove. The usual scene is the stove at the center of a group of older men in some country store passing time by telling tall tales (that get taller as the conversation goes on), discussing politics, the weather, local gossip, and what have you until, one-by-one, they take their leave and go on about the day's business, although there are often times when at least one or two hold court the entire day.



It seems only natural to use the special occasion of the start of the fifth decade of publication of the *Minor Planet Bulletin* to do the literary equivalent of a "stove talk gathering" and reflect on the changes and advances (and losses) that have occurred over the years. In this issue, you'll find other authors telling what they see in the mirror of time and maybe look into their crystal ball to guess at the future.

It would be easy for me as well to sit at the stove and regale in the past, telling of how I started observing asteroids systematically in 1999, mostly with the intent of finding new ones, and then, as it became obvious that professional surveys would soon corner the market, moving on to photometry; of how, some 14 years later, I'd have published more than 1000 lightcurves on these pages and my web site. I could include plots, charts, and numbers of how the number of lightcurves published in the *Minor Planet Bulletin* has risen exponentially the past decade, to where – until the last year or so – the vast majority of asteroid lightcurves published each year appeared in the *MPB*; or of becoming Assistant Editor in 2004 and taking over the reins of editor for a year while Richard Binzel took a sabbatical – ostensibly for scientific research at the Paris Observatory, but knowing it was really in the pursuit of French confectionary perfection. Then there's the nearly countless nights spent collecting photons after working the "day job" and taking naps in the car during lunch, all in the effort to burn the candle at both ends. My mirror holds barely more than a decade of memories and experiences. I can only imagine the depth of those who've been associated with the *MPB* since its beginning.

It would be easy to do all that, but I would prefer to spend a few moments to talk about the "ships and shoes and sealing wax" of current day backyard astronomy and how the *Minor Planet Bulletin* can and is evolving.

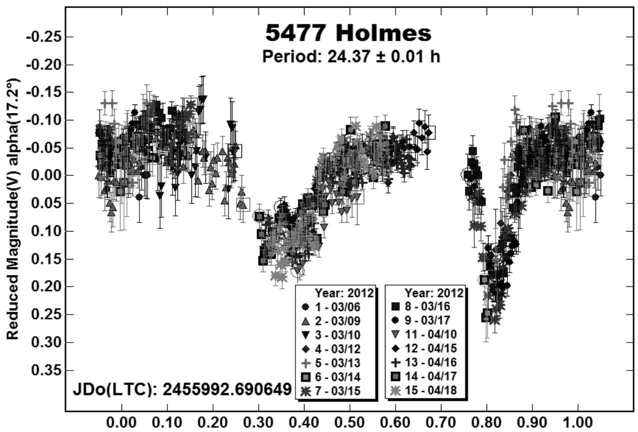


To start, I won't use the term "amateur", mainly because it isn't necessarily an accurate description. Is a person who holds a Ph.D. in a field of science, but not physics or astronomy, an "amateur astronomer"? The way the world works these days, people are often working – as professionals – in fields not directly tied to their degree. I think we all know someone who doesn't have a higher degree who is no less knowledgeable than a person who has a certificate hanging on the wall. So, permit me to use the term "backyard astronomer" if only to reflect that the equipment being used by that person is humble by comparison to what is considered to be "professional level". Even that's a bit tenuous now that a 4-meter telescope is considered a training instrument for grad students while the "real work" is done with much larger scopes and a 2-meter telescope is almost a "toy."

In the past decade, the backyard astronomer solely dedicated to the pursuit of making new asteroid discoveries has been nearly put out of business by surveys such as LONEOS, Catalina, and LINEAR. Even more prolific surveys are now on line and, with changes in the discovery rules at the Minor Planet Center, the landscape is even more bleak. Some have given up, either in disgust or dismay (or both). However, a large number have adapted their efforts or moved to other areas and so remain an important element in asteroid research.

Those still involved in astrometry now do critical follow-up to the new discoveries, thus assuring that the orbits are at least sufficiently established to know if a new near-Earth asteroid is a potential threat. Those astrometric data are also vital for more immediate purposes, such as refining the orbit for the current apparition to where radar observers, who have a very small field of view, can make observations. Make no mistake, some discovery is still going on within the backyard community, but the focus has changed, as it will need to do again once Pan-STARRS and LSST come fully on-line (assuming that they do). Those surveys will reach much deeper and so beyond the reach of even stack and track techniques used to work fainter objects. Those who have stuck with doing astrometry on a regular basis may have to adapt again. I'm sure they can and will.

A little more than a decade ago, the number of asteroids with well-known rotation periods was less than 2000. That number has more than doubled, to almost 4800. That vastly increased statistical pool has led to a number of important discoveries. For example, that the re-radiation of sunlight (the YORP effect) causes asteroid rotation rates to increase or decrease. The amount of change has even been measured for a small number of asteroids thanks in large part to the



contributions of backyard telescopes. Small binary asteroids were rare in 2000; dozens have been found since by carefully measuring the lightcurves of asteroids and seeing the results of occultations and or eclipses as a satellite orbits its parent body, as shown above.

However, finding the rotation rate of "just any asteroid" is no longer enough. The general statistical pool is fairly deep at this point and so the efforts have shifted to concentrate on specific projects such as following the Hungaria or Jupiter Trojan asteroids to determine the physical characteristics of a family; or the near-Earth (NEA) and small inner main-belt objects to look for more binaries and tumbling asteroids as well as the YORP effect; or to additional observations of objects at different apparitions to determine the orientation of the spin axis. Many of these studies will require detailed observations over many years, something that not even the large surveys may be able to do.

Even in photometry there is a "threat" of some sort from the planned surveys. New techniques allow finding the spin axis and rotation rate of an asteroid from a so-called "sparse" data set, which is what the surveys will provide. There will still be work for the backyard astronomer, whose job will become one of confirming results or handling the difficult cases of binary or tumbling asteroids, for which sparse data sets are of very limited use. As with astrometry, the large surveys will reach much fainter than any backyard telescope can manage, so follow-up on objects will be limited to brighter objects. That still leaves plenty of work for years to come and so the *Minor Planet Bulletin* will hardly be pressed for material as long as there are those willing to do the work.

Alan Harris has often used the phrase "dusty filing cabinet" to refer to lightcurve data stored on paper and buried in some deep, dark place. They are usually lost to time when the original author is gone and those who follow have no idea what to make of those rows and columns of numbers. Today's equivalent is the computer hard drive or a personal file "in the cloud".

Unless the data are made available to the community at large, they may be lost forever. Just as important, one person's junk is another person's treasure. Data that one person thinks of little or no use may be just what another person needs. There's no telling when or how any given data set might be of importance.

There is a growing discussion about the vast pool of asteroid lightcurve (time-series) photometry data that has and is being accumulated. For one, some NASA and NSF grants now require data management plans that outline what's to become of the data and how it will be made available to the research community and public. Sometimes there are time limits imposed on how long the data can be embargoed while the original researcher does his analysis.

In the last couple of years, the Minor Planet Center has taken on being a central repository for asteroid lightcurve photometry that is submitted using the ALCDEF standard (visit the ALCDEF site at *http://www.minorplanet.info/alcdef.html*). To date, more than 1.2 million observations have been submitted for more than 2000 asteroids. It's the largest known repository for such data.

However, there may be as many data, if not more, that are not readily available. In many cases, the results of the analysis based on those data are known, but the raw data are hard to obtain, if at all. This can impede other research, such as spin axis modeling to look for trends among specific asteroid families or the overall population. The MPC's ALCDEF site has been a great boon to such work but much more might be possible. Here, as noted below, the problem may be one of giving proper acknowledgement to the data providers and wanting to use the individual results as the foundation in a broader study.

More and more, professionals – as individuals and groups – are working with backyard astronomers. In some cases, the backyard astronomer works independently in that he obtains the data, publishes the results of his analysis in the *Minor Planet Bulletin* or other journal, and makes his data freely available. However, in all this his efforts are directed by a professional to accomplish specific goals. The professionals can reference the works published by the backyard astronomer, just as they would the work of another professional appearing in a journal, and so the backyard astronomer receives maximum credit and recognition for his efforts. This, I believe, is the most appropriate form of a pro-am collaboration since it fosters a mutual respect for each other's work and allows the data and results to get into the public forum in a timely way.

This is all the more a reasonable course since the *Minor Planet Bulletin* is now considered a refereed journal by NASA's Astrophysical Data Service (ADS). Articles in the *MPB* have long been indexed in the ADS but this next step, thanks due to Editor Richard Binzel, enhances the respectability of the papers and, more so, makes the *MPB* an acceptable journal for papers from professionals that may not be quite the level wanted by journals such as *Icarus* or *Astronomy and Astrophysics*.

However, there are many, sometimes delicate, issues involved with publishing results and making the original data available. A professional program may not care about the individual results so much as the "big picture" those results represent. For example, the previously mentioned studies on spin axis alignments, which are proving to be ever more important in developing theories about the asteroid population. To obtain these types of results and do the analysis based on those results can often take years of accumulating data and, for good reason in many cases, the intermediate results are held back to allow the professional to develop his ideas. Competition, unfortunately, is hot and heavy in scientific research.

When I've tried to encourage backyard astronomers to do asteroid photometry, the concern raised most often has been the time lag between sending the data to someone and seeing results. In astrometry work, observations submitted one day often appear the next day or just a few days later. A delay of months, even years, before a lightcurve appears in a journal, if at all, is often thought to be the equivalent of sending the data into a "black hole" with no immediate feedback or recognition. This is something that must be addressed when building pro-am collaborations since those are often the only rewards the backyard astronomer receives.

Before I took the plunge to live or die on NASA/NSF grants, my astronomy work was subsidized by the "day job" that often involved more than 40 hours a week. In reality, I was moonlighting at a second, full-time job that had no regard for the calendar. If it was clear, the telescopes ran weekdays, weekends, and holidays. Anything outside the two jobs was planned around the lunar calendar when possible. This burns up the "spousal permission units" in quick fashion.

The efforts and products of the backyard astronomer should not be considered just a means around budgetary constraints but as a chance to develop a strong, trained group of *colleagues* who are allowed to work within a group but maintain some independence while providing data and results that are directed towards specific goals. A professional at a pro-am meeting a few years ago failed to appreciate this and some of his comments drew a loud groan from the very people he was trying to recruit.

There is no simple or single solution to the issues of data and results sharing and distribution; collaboration and independence are sometimes mutually exclusive. Despite these challenges, dedicated observing and analysis programs involving the backyard astronomer should try to make them equal partners as much as possible. Anyone is more prone to work a little harder and sacrifice a little more if they think they are a full member of and in good standing with a team.

As we move into the fifth decade of the *Minor Planet Bulletin*, we are seeing papers with more than just lightcurves. Some include work on finding H-G parameters or doing lightcurve inversion to derive shapes and poles. I hope that this trend continues since it not only provides valuable information but raises the quality of and regard for the *Minor Planet Bulletin*. However, with the increasing level of work comes the need for more care in analysis, to compare and contrast with previous results, to provide complete and proper citations to earlier works, and more. This is happening as well but more can be done. I have no doubt the *MPB* contributors are equal to the challenge.

MPB PRODUCER'S RETROSPECTIVE

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(Received: 29 October Revised: 4 November)

My subscription began with *MPB* 10-1 in 1983. By coincidence, Rick Binzel had just taken over *MPB* editorial and production duties from Richard Hodgson, and Derald Nye had begun handling distribution. Fred Pilcher had become the section recorder.

In *MPB* 11-4 Binzel announced that *MPB* would be produced using a Macintosh computer. He "encouraged (and begged)" a volunteer with a Mac who was willing to type authors' manuscripts.

Have you ever had the feeling that something you are about to do is going to change the rest of your life? I had a Mac and spare time, so I volunteered, beginning with *MPB* 12-3 in 1985.

Initially I was just the typist. Authors mailed their manuscripts to Binzel in Texas, who forwarded them to me in Iowa. I entered the manuscripts using Apple's MacWrite, and printed them on a dot-matrix printer. I mailed the original manuscripts and proof copies to the authors, who then corresponded with editor Binzel if changes were needed. I mailed a floppy disk containing the computer manuscripts to Binzel (email was primitive in 1985). Once authors' corrections were incorporated, he printed each article on a dot-matrix printer, leaving blank holes for the separate figures and tables.

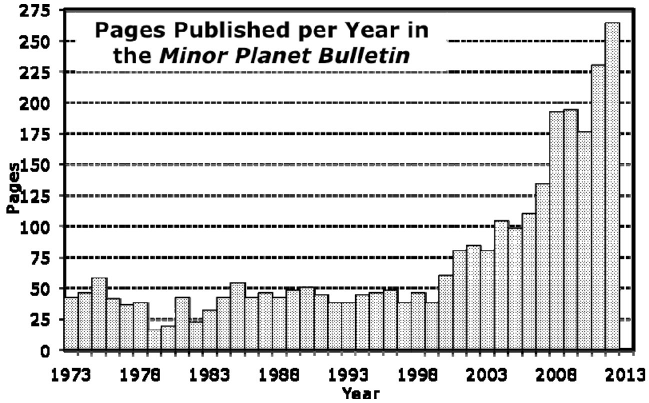
Binzel laid out each quarterly issue by literally cutting and pasting articles together. The master copy was oversized by 1/3 to improve the resolution of the dot-matrix typeface. A printshop reduced the master copy to actual size and reproduced the issues using an offset process and paper plates. The bulk was mailed to Nye in Arizona, who repackaged and mailed individual issues to subscribers.

Big changes happened toward the end of 1986. Binzel received his doctorate and took a research position in Arizona. A laser printer became available where I worked. Microsoft produced a capable version of Word for Macintosh. With these in mind, I offered to do more for *MPB* than just type and send proofs; I offered to take over the layout and printing duties. Binzel quizzed me; would such a printer always be available? Would I commit to five years of production duties? After my affirmative responses, Binzel accepted. *MPB* 14-1 (1987) was the first issue where I handled layout. The process was nearly the same as what Binzel did; print articles on a laser printer, cut-and-paste them into a master document, print the issues commercially, and mail the bulk to Nye.

MPB always contained a photoelectric photometry opportunity article with a list of asteroids to be observed. Binzel had been producing corresponding ephemerides, but in *MPB* 14-2 I took on that duty. Ephemerides were produced using a two-body program and elements from the annual *Ephemerides of Minor Planets*.

In 1988, Binzel became faculty at MIT. I moved to Texas to pursue graduate degrees in aerospace engineering. It was economical and acceptable to reproduce *MPB* 15-4 and beyond via photocopy instead of offset printing. Nye continued handling distribution.

In 1990 Brian Warner began publishing *Minor Planet Observer* after Jay Gunter's *Tonight's Asteroids* stopped in 1986. Warner's first *MPB* photometry article was in *MPB* 26-4 (1999). Warner became very active in the photometry community. He wrote a comprehensive how-to book, and began hosting a website for asteroid photometry results. His data-reduction program *Canopus* has been used by many observers to prepare lightcurves. The chart below shows the total number of pages yearly in *MPB*; the inflection after year 2000 is due to Warner's own contributions, and other observers entering the field, in large measure with Warner's book and *Canopus* paving the way.



After receiving my doctorate in 1996, I moved to California to work at NASA/JPL (from which I've just retired). I continued my role as *MPB* producer, sending authors' proofs, laying out the master copy of each issue, and getting it reproduced at a printshop.

I began using JPL's *Horizons* program to generate ephemerides for the suggested photometry targets. However, this stopped with *MPB* 25-4 (1998). Interested observers can use *Horizons* themselves; it's on the web.

Over time, authors' manuscripts became all-electronic, first being submitted to Binzel on floppy disk and then by email. Fewer and fewer authors submitted paper manuscripts for me to type, or with separate figures to mount. Finally, about 2005, laying out *MPB* became all electronic.

By this time Macintosh OS X and Microsoft Word could save the complete issue as a file in Adobe's portable-document format (pdf). While working on *MPB* 31-3, I emailed a pdf trial issue to Binzel to work out a layout problem. A light bulb went off; we could distribute *MPB* electronically via email or download. Doing so would save postage. *MPB* issues had become longer, heavier, and more expensive to mail. We sometimes held an article so an issue would not cross a weight threshold set by the post office.

We contemplated setting up a web site from which subscribers would download each issue. But maintaining user ids, passwords, and subscriptions might be onerous for our shoestring, all volunteer outfit. Starting with *MPB* 32-1 (2005), with Pilcher's approval, we made the *MPB* pdf freely available for download from Warner's *MPO* website. Paying subscribers could still get printed copies mailed to them. We solicited monetary donations to help defray production and postage costs which still continued.

The printed issue was mailed first, so that paying subscribers received their copy before the free electronic copy was available. (It was my idea that the electronic copy be made available on solstices and equinoxes; we are all astronomers.)

In 2005, the printshop duties moved from me in California to Nye in Arizona. Printing evolution continued, with a major decision in 2010 changing *MPB* printed issue distribution to "Institutions Only", for archival purposes. Individuals must download the electronic issue. Again, this was to reduce costs. This could potentially reduce the time spent laying out an issue; with so few printed copies, it would cost only a little extra to waste space after an article by automatically beginning the next at the top of the next column. However, habits die hard. I persist in laying out issues compactly, with little wasted space.

Issues continued growing in size, both pages and megabytes. The master pdf file has become too large to email to Warner. The nature of the articles has also changed. In the late 1980's sometimes there were more articles with predicted ephemerides than actual observations. (I once mocked up a one-page "Couch-Potato Bulletin – special all-predictions issue; contains no observations!") Almost all articles now involve CCD photometry – lightcurves and rotation periods, with the occasional pole determination or shape reconstruction, something I consider amazing. There are international collaborations to determine the periods of slow rotators. There's a sense that *MPB* has become nearly a professional journal, but still gladly accepts articles from amateurs.

I don't know what the future holds. We've never seriously considered publishing *MPB* on a bimonthly schedule instead of quarterly. I don't think we will afford printing the archival issues in color, even though lightcurve traces in authors' figures might be colored.

MPB DISTRIBUTOR'S RETROSPECTIVE

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Issue 40-1 starts the beginning of my 30th year as *MPB* Distributor. It is also the 30th year, or nearly so, for the real workers Rick Binzel and Bob Werner that make my job easy.

I was chosen for this voluntary job after I had put my name in the hat for it. I was working for IBM and had purchased a day one IBM PC and thought that it would help in keeping track of the subscriptions. I wrote my own addressing data storage format and an addressing program that fed an Epson printer to print mailing labels. As I recall the maximum number of paid subscribers reached around 170. But this started reducing when the *MPB* was made available electronically.

When the next two issues (within Volume 40) are published and I make the distribution of those printed copies to libraries and institutions, my service time to the *MPB* will equal the time I worked for IBM. So my role as *MPB* Producer turn out to be my longest job. IBM paid better! :-) But there are less headaches with the *MPB*.

LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2013 JANUARY-MARCH

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We present lists of asteroid photometry opportunities for objects reaching a favorable apparition and have no or poorly-defined lightcurve parameters. Additional data on these objects will help with shape and spin axis modeling via lightcurve inversion. We also include lists of objects that will be the target of radar observations. Lightcurves for these objects can help constrain pole solutions and/or remove rotation period ambiguities that might not come from using radar data alone.

We present lists of "targets of opportunity" for the period 2013 January-March. For background on the program details for each of the opportunity lists, refer to previous issues, e.g., *Minor Planet Bulletin* **36**, 188. In the first three sets of tables, "Dec" is the declination and "U" is the quality code of the lightcurve. See the asteroid lightcurve data base (LCDB) documentation for an explanation of the U code:

http://www.minorplanet.info/lightcurvedatabase.html

Objects with U = 1 should be given higher priority over those rated U = 2 or 2+ but not necessarily over those with no period. On the other hand, d*o not overlook asteroids with* U = 2/2+ *on the assumption that the period is sufficiently established.* Regardless, do not let the existing period influence your analysis since even high quality ratings have been proven wrong at times. Note that the lightcurve amplitude in the tables could be more or less than what's given. Use the listing only as a guide.

The first list is an *abbreviated list* of those asteroids reaching V < 14.5 at brightest during the period and have either no or poorly-constrained lightcurve parameters. An asterisk (*) after the name indicates that the asteroid is reaching one of its five brightest apparitions between the years 1995-2050.

The goal for these asteroids is to find a well-determined rotation rate. The target list generator on the CALL web site allows you to create custom lists for objects reaching V ≤ 18.0 during any month in the current year, e.g., limiting the results by magnitude and declination.

http://www.minorplanet.info/PHP/call_OppLCDBQuery.php

In a general note, small objects with periods up to 4 hours or even longer are possible binaries. For longer periods (4-6 hours or so), the odds of a binary may be less, but the bonus is that the size of the secondary, if it exists, is likely larger (see Pravec *et al.* (2010), *Nature* **466**, 1085-1088), thus eclipses, if they occur, will be deeper and easier to detect.

The Low Phase Angle list includes asteroids that reach very low phase angles. The "α" column is the minimum solar phase angle for the asteroid. Getting accurate, calibrated measurements (usually V band) at or very near the day of opposition can provide important information for those studying the "opposition effect." You will have the best chance of success working objects with low amplitude and periods that allow covering, e.g., a maximum, every night. Objects with large amplitudes and/or long periods are much more difficult for phase angle studies since, for proper analysis, the data have to be reduced to the average magnitude of the asteroid for each night. Without knowing the period and/or the amplitude at the time, that reduction becomes highly uncertain. As an aside, some use the maximum light to find the phase slope parameter (*G*). However, this can produce a significantly different value for both *H* and *G* versus using average light, which is the method used for values listed by the Minor Planet Center.

The third list is of those asteroids needing only a small number of lightcurves to allow spin axis and/or shape modeling. Those doing work for modeling should contact Josef Ďurech at the email address above and/or visit the Database of Asteroid Models from Inversion Techniques (DAMIT) web site for existing data and models:

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

The fourth list gives a brief ephemeris for planned radar targets. Supporting optical observations to determine the lightcurve period, amplitude, and shape are needed to supplement the radar data. *High-precision work, 0.01-0.02 mag, is preferred, especially if the object is a known or potential binary*. Those obtaining lightcurves in support of radar observations should contact Dr. Benner directly at the email given above.

Future radar targets:
http://echo.jpl.nasa.gov/~lance/future.radar.nea.periods.html

Past radar targets:
http://echo.jpl.nasa.gov/~lance/radar.nea.periods.html

Arecibo targets:
http://www.naic.edu/~pradar/sched.shtml
http://www.naic.edu/~pradar

Goldstone targets:
http://echo.jpl.nasa.gov/asteroids/goldstone_asteroid_schedule.html

As always, we encourage observations of asteroids even if they have well-established lightcurve parameters and especially if they are lacking good spin axis and/or shape model solutions. Every lightcurve of sufficient quality supports efforts to resolve a number of questions about the evolution of individual asteroids and the general population. For example, pole directions are known for only about 30 NEAs out of a population of 8000. This is hardly sufficient to make even the most general of statements about NEA pole alignments, including whether or not the thermal YORP effect is forcing pole orientations into a limited number of preferred directions (see La Spina *et al.*, 2004, *Nature* **428**, 400-401). Data from many apparitions can help determine if an asteroid's rotation rate is being affected by YORP, which can also cause the rotation rate of a smaller, irregularly-shaped asteroid to increase or decrease. See Lowry *et al.* (2007) *Science* **316**, 272-274 and Kaasalainen *et al.* (2007) *Nature* **446**, 420-422.

The ephemeris listings for the optical-radar listings include lunar elongation and phase. Phase values range from 0.0 (new) to 1.0 (full). If the value is positive, the moon is waxing – between new and full. If the value is negative, the moon is waning – between full and new. The listing also includes the galactic latitude. When this value is near 0°, the asteroid is likely in rich star fields and so may be difficult to work. It is important to emphasize that the ephemerides that we provide are only guides for when you might observe a given asteroid. Obviously, you should use your discretion and experience to make your observing program as effective as possible.

Once you've analyzed your data, it's important to publish your results. Papers appearing in the *Minor Planet Bulletin* are indexed in the Astrophysical Data System (ADS) and so can be referenced by others in subsequent papers. It's also important to make the data available at least on a personal website or upon request.

Funding for Warner and Harris in support of this article is provided by NASA grant NNX10AL35G and by National Science Foundation grant AST-1032896.

Lightcurve Opportunities

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
275	Sapientia	01 02.4	12.1	+19	14.766	0.06	2
1024	Hale	01 02.4	14.8	+40			
3211	Louispharailda	01 02.4	15.0	+39			
467	Laura	01 03.3	14.4	+29	36.7	0.14	1
269	Justitia	01 04.9	14.0	+16	16.545	0.14-0.25	2
1128	Astrid	01 06.1	14.6	+24	10.228	0.29	2+
2448	Sholokhov	01 07.6	14.6	+11	10.065	0.63	2+
3115	Baily	01 08.5	13.7	+13	16.22	0.08-0.14	2+
555	Norma	01 09.5	14.1	+21	19.55	0.06-0.20	2+
577	Rhea	01 10.6	14.3	+27	12.266	0.21-0.31	2
3063	Makhaon	01 12.0	14.9	+21	8.64	0.03-0.15	2
2950	Rousseau	01 12.8	14.1	+22	18.228	0.30	2
1242	Zambesia	01 13.9	13.6	+35	17.305	0.24	2
4807	Noboru	01 14.3	14.9	+22			
9780	Bandersnatch	01 16.8	14.7	+21	8.234	0.16	2+
1328	Devota	01 17.6	15.0	+13	17.49	0.20	2-
2569	Madeline	01 20.5	14.3	+32		0.1	
1311	Knopfia	01 20.6	14.9	+16	9.65	1.3	1+
806	Gyldenia *	01 22.0	14.5	+40	14.45	0.10-0.27	2
309	Fraternitas	01 25.3	14.6	+23	13.2	0.12	2
393	Lampetia	01 25.5	13.8	+0	38.7	0.14	2-
814	Tauris	01 26.3	13.4	+37	35.8	0.20	2
1544	Vinterhansenia	01 27.9	14.4	+24	13.77	0.18	2
395	Delia	01 29.4	14.4	+14	19.71	0.25	2
47035	1998 WS	01 31.7	14.5	+69	3.99	0.08-0.15	2
4874	Burke	02 01.6	14.8	+19	3.657	0.22	2+
3141	Buchar	02 04.8	14.9	+18	11.41	0.47	2+
838	Seraphina	02 05.4	14.7	+2	15.67	0.07-0.30	2
2040	Chalonge	02 05.4	14.8	+38			
705	Erminia	02 06.6	12.6	+43	53.96	0.05-0.17	2
784	Pickeringia *	02 06.7	14.0	+31	13.17	0.20-0.40	2
1724	Vladimir	02 06.9	14.7	+7	12.57	0.14	2
1145	Robelmonte	02 08.1	14.4	+20	9.01	0.05-0.18	2
3940	Larion	02 08.3	14.9	-21	84.	0.08-0.31	2
319	Leona	02 09.6	14.6	+4	9.6	0.03	1
645	Agrippina	02 10.1	13.9	+21	32.6	0.11-0.18	2
530	Turandot	02 11.8	14.6	+17	19.947	0.10-0.16	2+
2088	Sahlia	02 13.6	14.5	+19	10.37	0.12	2
331	Etheridgea	02 14.3	14.2	+20		0.05	1
375	Ursula	02 14.8	12.2	+17	16.83	0.17	2
764	Gedania	02 15.2	14.1	+0	24.975	0.09-0.35	2
879	Ricarda	02 15.3	14.9	-4	82.9	0.37	2

Lightcurve Opportunities (cont'd)

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
924	Toni	02 16.9	13.7	+12	21.	0.1	1
498	Tokio	02 19.5	13.5	+21	30.	0.18	1
2719	Suzhou	02 19.5	14.7	+12			
4350	Shibecha	02 19.9	14.7	+32	2.89	0.11-0.16	2+
1159	Granada	02 20.1	14.7	+18	31.	0.28	2
6618	1936 SO	02 20.1	14.5	+16	8.297	0.20	2+
605	Juvisia	02 21.2	14.7	+16	15.93	0.26	2
1622	Chacornac	02 22.9	14.7	+16	12.206	0.25	2
1182	Ilona	02 23.6	14.0	+11	29.8	1.2	2
609	Fulvia	02 24.6	14.4	+9	20.	0.08	1+
407	Arachne	03 02.8	12.6	-1	22.62	0.31-0.45	2
619	Triberga	03 02.8	13.5	-2	29.412	0.30-0.45	2
192642	1999 RD32	03 04.5	14.5	+2	17.08	0.28	2
6329	Hikonejyo	03 04.8	15.0	+17	8.066	0.18	2
1502	Arenda	03 06.3	14.7	+2	45.8	0.4	2
1558	Jarnefelt	03 08.7	14.9	+16	18.22	0.40	2
2540	Blok	03 10.0	15.0	+4			
746	Marlu	03 10.1	15.0	+9	7.787	0.23	2
7895	Kaseda	03 16.4	15.0	+14	5.11	0.10	2+
791	Ani	03 17.0	14.5	+17	16.72	0.17-0.38	2
1228	Scabiosa	03 17.0	14.8	-2			
3747	Belinskij	03 17.3	15.0	+25	3.31	0.02	1
4892	Chrispollas	03 18.0	15.0	-7		0.10	
1029	La Plata	03 21.2	14.5	+1	15.31	0.26-0.58	2
1269	Rollandia	03 21.5	13.7	+2	15.4	0.08	2
1114	Lorraine	03 23.1	14.5	-4	33.	0.16	1
741	Botolphia	03 26.2	13.3	+10	23.93	0.15- 0.4	2-
1048	Feodosia	03 27.2	12.9	+18	10.46	0.14	2
1465	Autonoma	03 27.6	14.8	+2	4.88	0.13	2
823	Sisigambis	03 28.2	13.3	-9	146.	0.08- 0.6	2
379	Huenna	03 30.1	13.8	-3	14.14	0.09	2
1001	Gaussia	03 31.7	14.8	-16	9.17	0.04-0.16	2-
1409	Isko	03 31.9	14.7	-2	11.643	0.20	2

Low Phase Angle Opportunities

#	Name	Date	α	V	Dec	Period	Amp	U
211	Isolda	01 01.7	0.73	11.1	+21	18.365	0.09-0.14	3
410	Chloris	01 02.6	0.43	12.9	+24	32.50	0.28	3
300	Geraldina	01 03.8	0.29	14.0	+24	6.8423	0.15-0.32	3
758	Mancunia	01 09.5	0.22	11.8	+22	12.7253	0.15-0.27	3
543	Charlotte	01 12.9	0.20	13.0	+22	10.718	0.26	3
182	Elsa	01 15.8	0.29	11.1	+22	80.088	0.72	3
1011	Laodamia	01 27.2	0.91	12.6	+17	5.17247	0.44	3
1113	Katja	02 07.3	0.79	13.0	+17	18.465	0.15	3
201	Penelope	02 08.3	0.80	12.7	+13	3.7474	0.11-0.73	3
108	Hecuba	02 11.2	0.91	12.4	+17	17.859	0.05-0.17	3-
100	Hekate	02 11.4	0.65	12.6	+16	27.066	0.11-0.23	3
551	Ortrud	02 20.7	0.17	13.2	+11	13.05	0.09-0.18	2
624	Hektor	02 20.7	0.85	14.0	+15	6.924	0.1 -1.1	3
75	Eurydike	02 23.9	0.81	13.8	+12	5.357	0.10-0.15	3
192	Nausikaa	02 24.9	0.46	10.8	+10	13.625	0.15-0.40	3
65	Cybele	02 25.9	0.08	11.3	+09	6.0814	0.04-0.12	3
175	Andromache	03 02.2	0.70	13.7	+10	8.324	0.21-0.30	3
63	Ausonia	03 02.4	0.31	10.4	+06	9.298	0.15-0.95	3
215	Oenone	03 06.0	0.57	13.2	+07	>20.	0.1	2
577	Rhea	03 08.1	0.71	14.0	+03	12.2667	0.21-0.31	2
206	Hersilia	03 09.6	0.88	12.2	+07	11.11	0.08-0.14	3
180	Garumna	03 10.7	0.40	12.9	+03	23.866	0.42-0.6	3
29	Amphitrite	03 12.8	0.30	9.1	+04	5.3921	0.01-0.15	3
1651	Behrens	03 16.4	1.00	13.9	+00	34.34	0.16	2
693	Zerbinetta	03 18.2	0.74	13.5	-01	11.475	0.14-0.29	3-
74	Galatea	03 20.0	0.52	13.4	-01	17.268	0.08-0.16	3
177	Irma	03 20.0	0.12	14.0	+00	13.856	0.30-0.37	3-
927	Ratisbona	03 21.5	0.94	13.5	+02	12.994	0.12	2
1396	Outeniqua	03 28.3	0.58	13.9	-04	3.08158	0.42	3
490	Veritas	04 01.4	0.87	13.1	-02	7.930	0.33-0.58	3
203	Pompeja	04 01.5	0.69	12.5	-06	24.052	0.10	3
158	Koronis	04 03.8	0.51	13.2	-07	14.218	0.28-0.43	3
119	Althaea	04 10.3	0.22	12.0	-09	11.484	0.23-0.36	3

Shape/Spin Modeling Opportunities

There are two lists here. The first is for objects for which good occultation profiles are available. These are used to constrain the models obtained from lightcurve inversion, eliminating ambiguous solutions and fixing the size of asteroid. Lightcurves are needed for modeling and/or to establish the rotation phase angle at the time the profile was obtained. The second list is of those objects for which another set of lightcurves from one more apparitions will allow either an initial or a refined solution.

Occultation Profiles Available

#	Name	Brightest Date	Mag	Dec	LCDB DATA Period	Amp	U
200	Dynamene	01 01.	12.4	+22	37.394	0.10	3
40	Harmonia	01 01.	10.6	+13	8.910	0.13-0.36	3
230	Athamantis	01 01.	11.3	+12	24.0055	0.1 0.26	3
420	Bertholda	01 01.	13.5	+19	11.04	0.24-0.29	3
27	Euterpe	01 01.	11.0	+03	10.4082	0.13-0.21	3
466	Tisiphone	01 03.4	12.9	+27	8.824	0.12-0.16	3
153	Hilda	01 06.4	13.6	+14	5.9587	0.05-0.20	3
204	Kallisto	01 06.5	13.3	+11	19.489	0.09-0.26	3
790	Pretoria	01 15.1	13.7	+03	10.37	0.05-0.18	3
70	Panopaea	01 17.3	12.6	+36	15.797	0.06-0.12	3
757	Portlandia	01 27.0	12.9	+32	6.5837	0.24-0.45	3
490	Veritas	01 27.8	13.0	+08	7.930	0.33-0.58	3
578	Happelia	01 29.2	14.0	+27	10.061	0.11-0.16	3
25	Phocaea	02 03.8	12.4	-13	9.9341	0.03-0.25	3
1437	Diomedes	02 08.2	14.9	+14	24.49	0.22-0.70	3-
530	Turandot	02 11.8	14.6	+17	19.947	0.10-0.16	2+
375	Ursula	02 14.8	12.2	+17	16.83	0.17	2
386	Siegena	02 16.6	11.7	+03	9.763	0.11-0.18	3
498	Tokio	02 19.5	13.5	+21	30.	0.18	1
144	Vibilia	02 28.1	12.3	+15	13.819	0.13-0.20	3
559	Nanon	03 08.6	13.0	+16	10.059	0.09-0.26	3
791	Ani	03 17.0	14.5	+17	16.72	0.17-0.38	2
106	Dione	03 17.9	12.4	+06	16.26	0.08	3
93	Minerva	03 21.7	11.2	+00	5.982	0.04-0.20	3
334	Chicago	03 22.7	13.0	+04	7.361	0.15-0.67	3
49	Pales	03 25.9	12.9	-06	10.42	0.18	3

Inversion Modeling Candidates

#	Name	Brightest Date	Mag	Dec	LCDB Data Period	Amp	U
446	Aeternitas	01 01.	13.6	+23	15.7413	0.36-0.51	3
1665	Gaby	01 01.	14.8	+10	66.	0.27	2
852	Wladilena	01 01.	14.2	+04	4.6134	0.28-0.32	3
281	Lucretia	01 01.	14.9	+18	4.348	0.38	3
622	Esther	01 01.	13.2	+01	47.5	0.57	2
270	Anahita	01 01.	12.2	+16	15.06	0.25-0.34	3
915	Cosette	01 01.	14.0	+30	4.445	0.30-1.02	3
1282	Utopia	01 01.	14.9	+37	13.623	0.28-0.36	3
1188	Gothlandia	01 01.	15.0	+10	3.4916	0.59-0.78	3
1243	Pamela	01 01.	14.3	+14	26.017	0.42-0.71	2
336	Lacadiera	01 01.	12.8	+17	13.70	0.27-0.34	3
966	Muschi	01 01.	14.3	+31	5.355	0.31	3
391	Ingeborg	01 02.3	14.3	-15	26.391	0.22-0.79	3
1185	Nikko	01 17.4	14.1	+28	3.79	0.27-0.50	3
235	Carolina	01 17.5	13.1	+31	17.610	0.30-0.38	3
233	Asterope	01 19.5	12.1	+09	19.70	0.25-0.55	3
1013	Tombecka	01 20.7	12.7	+42	6.053	0.44	3
629	Bernardina	01 21.8	13.5	+28	3.763	0.23-0.39	3
399	Persephone	01 26.8	13.0	+32	9.136	0.40	3
540	Rosamunde	01 27.2	13.0	+09	9.336	0.40-0.66	3-
573	Recha	01 30.9	13.8	+25	7.16633	0.20-0.34	3
1687	Glarona	02 04.4	14.3	+19	6.3	0.75	3
753	Tiflis	02 05.9	13.7	+31	9.85	0.35-0.8	3
784	Pickeringia	02 06.7	14.0	+31	13.17	0.20-0.40	2
1379	Lomonosowa	02 14.3	13.8	+03	24.488	0.63	3
1301	Yvonne	02 17.5	13.8	-04	7.320	0.52-0.90	3
553	Kundry	02 18.7	14.5	+20	12.605	0.41-0.61	3
605	Juvisia	02 21.2	14.7	+16	15.93	0.26	2
746	Marlu	03 10.1	15.0	+09	7.787	0.23	2
510	Mabella	03 10.9	13.5	-03	19.4	0.25	3
1889	Pakhmutova	03 19.6	15.0	+16	17.490	0.50	3-
823	Sisigambis	03 28.2	13.3	-09	146.	0.08-0.6	2

Radar-Optical Opportunities

Use the ephemerides below as a guide to your best chances for observing, but remember that photometry may be possible before and/or after the ephemerides given below. Some of the targets may be too faint to do accurate photometry with backyard telescopes. However, accurate astrometry using techniques such as "stack and track" is still possible and can be helpful for those asteroids where the position uncertainties are significant. Note that the intervals in the ephemerides are not always the same and that *geocentric* positions are given. Use these web sites to generate updated and *topocentric* positions:

MPC: *http://www.minorplanetcenter.org/iau/MPEph/MPEph.html*
JPL: *http://ssd.jpl.nasa.gov/?horizons*

In the ephemerides below, ED and SD are, respectively, the Earth and Sun distances (AU), V is the estimated Johnson V magnitude, and α is the phase angle. SE and ME are the great circles distances (in degrees) of the Sun and Moon from the asteroid. MP is the lunar phase and GB is the galactic latitude. "PHA" in the header indicates that the object is a "potentially hazardous asteroid", meaning that at some (long distant) time, its orbit might take it very close to Earth.

Some of the objects below are repeats from the previous issue of the *Minor Planet Bulletin* and those with opportunities extending into the next quarter may be featured again in the next issue of the *MPB*.

(214869) 2007 PA8 (2013 Jan, H = 16.2, PHA)
2007 PA8 is an NEA with an estimated diameter of 1.6 km. There are no entries in the LCDB.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	12 09.1	-04 14	0.30	1.06	16.2	66.7	97	43	-0.88	+57
01/06	12 10.8	-03 43	0.32	1.09	16.2	61.6	102	22	-0.41	+58
01/11	12 11.2	-03 06	0.34	1.13	16.3	56.4	107	96	-0.01	+58
01/16	12 10.0	-02 23	0.35	1.17	16.3	51.1	113	168	+0.22	+59
01/21	12 07.2	-01 32	0.37	1.21	16.3	45.8	119	129	+0.69	+59
01/26	12 03.1	-00 35	0.38	1.25	16.3	40.3	125	68	+0.99	+60
01/31	11 57.6	+00 29	0.40	1.29	16.3	34.8	132	5	-0.85	+60
02/05	11 51.1	+01 38	0.42	1.33	16.3	29.2	139	68	-0.34	+61

2010 BB (2012 Dec – 2013 Jan, H = 20.0, PHA)
This small (0.3 km) NEA has no entries in the LCDB. The observing window extends into 2013 January, assuming good photometry can still be obtained at V ~ 18.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/20	20 22.7	+20 09	0.06	0.95	18.8	119.8	57	51	+0.48	-10
12/23	21 24.0	+20 49	0.06	0.96	18.0	111.4	65	65	+0.76	-21
12/26	22 34.8	+19 46	0.06	0.97	17.3	101.1	76	81	+0.95	-33
12/29	23 43.8	+16 57	0.06	0.98	17.0	90.7	86	101	-1.00	-43
01/01	00 41.3	+13 23	0.06	0.99	16.9	82.1	94	126	-0.88	-49
01/04	01 25.0	+10 03	0.07	1.00	17.0	76.0	100	156	-0.62	-52
01/07	01 57.6	+07 20	0.08	1.01	17.2	72.0	103	168	-0.30	-52
01/10	02 22.3	+05 13	0.10	1.01	17.4	69.5	105	131	-0.05	-51

2002 AY1 (2012 Dec, H = 20.9, PHA)
There are no entries in the LCDB for this NEA of about 0.2 km size. The semi-major axis is only 0.78 AU. With an orbital eccentricity of 0.44, the asteroid distance from the Sun ranges from about 0.44 to 1.12 AU, or almost entirely within the Earth's orbit.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/20	11 40.1	+59 54	0.19	1.07	19.5	58.7	112	118	+0.48	+55
12/23	11 39.5	+61 56	0.16	1.06	19.1	58.2	114	99	+0.76	+53
12/26	11 36.3	+64 51	0.14	1.05	18.6	57.7	116	79	+0.95	+50
12/29	11 27.3	+69 19	0.11	1.04	18.1	57.3	117	64	-1.00	+46
01/01	10 54.4	+76 44	0.08	1.02	17.4	57.4	119	68	-0.88	+38
01/04	04 22.7	+84 04	0.06	1.01	16.7	59.9	117	96	-0.62	+23
01/07	00 54.9	+54 37	0.04	0.99	16.3	72.1	106	137	-0.30	-8
01/10	00 31.0	+12 31	0.04	0.98	17.3	95.0	82	107	-0.05	-50

(99942) Apophis (2012 Dec – 2013 Feb, H = 19.3, PHA)
This is probably the most famous and debated NEA of recent times. The rotation period for the 400 meter NEA is about 30.4 h,

based on observations in 2005 analyzed by Behrend. Again, such a period is best confirmed and refined by several observers at multiple longitudes, in this case, those south of the equator.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/10	11 38.1	-26 13	0.11	0.96	17.9	99.9	74	34	-0.16	+34
12/20	10 56.7	-27 13	0.10	0.99	17.2	83.1	91	153	+0.48	+29
12/30	10 09.4	-27 11	0.10	1.02	16.6	66.5	108	55	-0.98	+23
01/09	09 13.6	-24 52	0.10	1.04	16.1	50.0	126	98	-0.11	+16
01/19	08 16.0	-19 16	0.10	1.06	15.8	36.3	140	101	+0.50	+9
01/29	07 29.7	-11 32	0.11	1.08	16.0	31.6	145	42	-0.96	+3
02/08	07 00.4	-03 55	0.13	1.09	16.5	36.3	139	158	-0.07	+0
02/18	06 46.7	+02 23	0.16	1.10	17.1	43.8	130	45	+0.52	+0

(52762) 1998 MT24 (January, H = 14.6)
This NEA has an estimated diameter of 3.5 km. Pravec *et al.* found a period of 12.066 h based on observations in 1998. Given that the period is so closely commensurate with an Earth day, a collaboration among observers at widely-separated longitudes will have a better chance of producing a secure lightcurve and period.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	11 02.0	+25 13	0.53	1.34	15.5	38.3	122	28	-0.88	+65
01/06	11 09.0	+21 04	0.46	1.30	15.1	38.7	124	49	-0.41	+66
01/11	11 15.9	+15 26	0.38	1.25	14.7	39.4	126	114	-0.01	+65
01/16	11 23.0	+07 29	0.32	1.20	14.2	40.6	127	172	+0.22	+61
01/21	11 30.8	-03 57	0.26	1.16	13.8	43.6	126	122	+0.69	+53
01/26	11 40.2	-20 03	0.22	1.11	13.5	50.0	120	71	+0.99	+40
01/31	11 53.5	-40 14	0.21	1.07	13.6	60.6	109	38	-0.85	+21
02/05	12 17.0	-60 24	0.22	1.03	14.0	72.5	95	57	-0.34	+2

3752 Camillo (January-March, H = 15.5)
There is a chance that this NEA is a tumbler, i.e., in non-principal axis rotation (see Pravec *et al.*, 2005). That and the long period of 37.846 h make this another candidate for a collaborative effort. In this case, calibrating all the data to a common system to within 0.01-0.02 mag will be very important. The estimated diameter is 2.5 km.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/15	12 40.6	-62 56	0.47	1.00	16.2	74.0	78	109	+0.13	+0
01/25	12 57.4	-54 31	0.33	1.02	15.4	74.0	87	107	+0.95	+8
02/04	13 15.0	-33 38	0.20	1.05	14.2	65.9	103	31	-0.45	+29
02/14	13 31.8	+20 10	0.15	1.08	13.0	46.9	127	149	+0.16	+78
02/24	13 44.3	+61 35	0.25	1.12	14.3	51.7	117	71	+0.96	+54
03/06	13 46.3	+75 41	0.39	1.16	15.5	54.7	107	103	-0.38	+41
03/16	13 28.6	+81 11	0.54	1.21	16.2	54.2	100	82	+0.18	+36
03/26	12 51.0	+83 12	0.68	1.25	16.8	52.5	95	83	+0.98	+34

(137199) 1999 KX4 (January, H = 16.8)
There are no entries in the LCDB for this NEA, which has an estimated size of 1.2 km. This makes it a little large to expect a rotation period of < 2 hours, but the first rule of good science is never assume.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	10 03.4	+19 17	0.30	1.21	16.2	35.7	134	13	-0.88	+51
01/06	10 23.7	+23 23	0.27	1.19	15.9	35.5	135	59	-0.41	+56
01/11	10 47.6	+28 14	0.25	1.17	15.7	36.3	135	123	-0.01	+63
01/16	11 16.1	+33 42	0.23	1.15	15.6	38.3	133	146	+0.22	+68
01/21	11 50.3	+39 22	0.22	1.14	15.5	41.8	130	104	+0.69	+72
01/26	12 30.9	+44 42	0.21	1.12	15.5	46.3	125	67	+0.99	+72
01/31	13 17.1	+49 05	0.21	1.10	15.6	51.4	119	56	-0.85	+67

(136993) 1998 ST49 (January, H = 17.6)
Galad (2007) found a period of 2.302 h and amplitude of 0.11 mag for this near-Earth asteroid. These make it an ideal candidate for being binary even though he reported no indications of such. The phase angle bisector longitude this time around is about 100° from the time of Galad's observations. If the viewing geometry was not right the first time, it's about as likely as can be that it will be this time. In which case, you'll need observations on the order 0.01-0.02 mag precision to look for evidence of a satellite.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	10 03.4	+19 17	0.30	1.21	16.2	35.7	134	13	-0.88	+51
01/06	10 23.7	+23 23	0.27	1.19	15.9	35.5	135	59	-0.41	+56
01/11	10 47.6	+28 14	0.25	1.17	15.7	36.3	135	123	-0.01	+63
01/16	11 16.1	+33 42	0.23	1.15	15.6	38.3	133	146	+0.22	+68
01/21	11 50.3	+39 22	0.22	1.14	15.5	41.8	130	104	+0.69	+72
01/26	12 30.9	+44 42	0.21	1.12	15.5	46.3	125	67	+0.99	+72
01/31	13 17.1	+49 05	0.21	1.10	15.6	51.4	119	56	-0.85	+67

2008 DG17 (February, H = 19.7)
This NEA has an estimated effective diameter of 0.3 km. This is at the upper limit that roughly defines the potential for it being a superfast rotator (P < 2 hours). Keep that in mind as you make your observations, possibly keeping exposures as short as possible until you have a good indication of the rotation period.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/05	11 10.5	+58 46	0.18	1.12	17.9	40.9	132	100	-0.34	+54
02/07	10 39.0	+56 16	0.16	1.11	17.5	37.8	137	120	-0.14	+52
02/09	10 03.3	+52 13	0.14	1.10	17.1	33.6	142	137	-0.02	+50
02/11	09 25.3	+45 52	0.12	1.09	16.6	28.6	148	139	+0.01	+45
02/13	08 47.2	+36 30	0.10	1.08	16.2	24.1	153	122	+0.09	+38
02/15	08 11.4	+23 58	0.10	1.07	16.0	24.4	153	95	+0.24	+28
02/17	07 39.5	+09 35	0.09	1.07	16.2	32.1	145	66	+0.42	+15
02/19	07 12.0	-04 14	0.10	1.06	16.6	42.9	133	43	+0.61	+3

2012 DA14 (February, H = 24.4, Very Close Approach)
This is the highlight object of the group. On February 15, it will come to about 58000 km distance from Earth. According to the Minor Planet Center ephemeris service and based on orbital elements in mid-September 2012, the asteroid will be moving at a rate of more than 30 *arcminutes* per minute around 20 UT and be V ~ 8.2. This will allow short exposures without too much trailing, although scintillation noise for exposures of only 1-2 seconds may dominate the data.

The ephemeris is only a guideline since it is geocentric and the elements may be improved considerably prior to closest approach. What is particularly noteworthy, however, is that in the course of only one day, Feb 15-16, the asteroid moves from near the south celestial pole to the north. Also interesting is that of 2012 September, the asteroid is *not* listed on the MPC site as being potentially hazardous.

There is every possibility that this will be a super-fast rotator, with a period on the order of a few minutes. Complicating matters will be the significant range of phase angles, over which the amplitude and shape of the lightcurve could change dramatically. In addition, light-time and phase angle corrections will have to be done for each observation and not use constant correction values based on an average time in order to properly de-trend the data. Despite these difficulties, lightcurve data will be of enormous help when combined with radar data in modeling the shape and spin axis.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/13	00 21.0	-71 44	0.01	0.98	19.0	116.5	63	75	+0.09	-45
02/14	00 20.6	-72 37	0.01	0.98	18.0	115.8	64	81	+0.16	-44
02/15	00 18.0	-75 37	0.00	0.99	16.1	113.2	67	88	+0.24	-41
02/16	12 50.7	+76 05	0.00	0.99	11.7	65.2	115	89	+0.33	+43
02/17	13 01.2	+85 07	0.01	0.99	15.7	73.8	106	77	+0.42	+32
02/18	13 05.5	+86 02	0.01	0.99	17.1	74.7	105	73	+0.52	+31
02/19	13 07.8	+86 23	0.02	0.99	17.9	75.1	104	72	+0.61	+31
02/20	13 09.0	+86 34	0.02	0.99	18.5	75.3	104	71	+0.70	+31

1685 Toro (February-April, H = 14.2)

The rotation period of this NEA is fairly well stabled at 10.195 h. However, it is a good candidate for YORP spin-up/down, meaning that data from each succeeding apparition can be used to determine if the period is changing slowly over time.

It's important to note that the shape and amplitude of the curve can change significantly over an apparition, e.g., see Warner, *http://www.minorplanetobserver.com/pdolc/A1685_2012.HTM,* which also shows that the synodic period can change over a relatively short time. If you get a plan a protracted campaign, it would be good to subdivide it into blocks of dates, each having a relatively small range of phase angles and treating them as stand-alone sets. Putting all the data into a single set may not only affect the final solution but hide critical data about the lightcurve shape and amplitude vital to good modeling.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/13	00 21.0	-71 44	0.01	0.98	19.0	116.5	63	75	+0.09	-45
02/14	00 20.6	-72 37	0.01	0.98	18.0	115.8	64	81	+0.16	-44
02/15	00 18.0	-75 37	0.00	0.99	16.1	113.2	67	88	+0.24	-41
02/16	12 50.7	+76 05	0.00	0.99	11.7	65.2	115	89	+0.33	+43
02/17	13 01.2	+85 07	0.01	0.99	15.7	73.8	106	77	+0.42	+32
02/18	13 05.5	+86 02	0.01	0.99	17.1	74.7	105	73	+0.52	+31
02/19	13 07.8	+86 23	0.02	0.99	17.9	75.1	104	72	+0.61	+31

(329614) 2003 KU2 (March, H = 19.0, PHA)

Coming back after a close approach in 2012 July, this NEA was found to have a period of 3.278 h (Hicks *et al.*, 2012). The estimated size is about 0.9 km.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/10	12 38.7	+05 54	1.28	2.24	19.5	8.5	161	137	-0.04	+69
03/15	12 34.2	+06 15	1.25	2.23	19.3	6.3	166	151	+0.11	+69
03/20	12 29.1	+06 35	1.23	2.22	19.2	4.5	170	92	+0.53	+69
03/25	12 23.8	+06 54	1.22	2.21	19.1	4.0	171	31	+0.93	+69
03/30	12 18.4	+07 10	1.21	2.20	19.2	5.2	168	43	-0.91	+69
04/04	12 12.9	+07 22	1.21	2.19	19.3	7.3	164	114	-0.41	+68
04/09	12 07.8	+07 30	1.22	2.18	19.4	9.8	158	168	-0.02	+68

IN THIS ISSUE

This list gives those asteroids in this issue for which physical observations (excluding astrometric only) were made. This includes lightcurves, color index, and H-G determinations, etc. In some cases, no specific results are reported due to a lack of or poor quality data. The page number is for the first page of the paper mentioning the asteroid. EP is the "go to page" value in the electronic version.

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The deadline for the next issue (40-2) is January 15, 2013. The deadline for issue 40-3 is April 15, 2013.