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## ROTATION PERIODS AND *R* MAGNITUDES OF THREE KORONIS FAMILY MEMBERS

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We report synodic rotation periods for three Koronis family asteroids: 1443 Ruppina, 5.880 ± 0.001 h; 1848 Delvaux, 3.639 ± 0.001 h; and 2144 Marietta, 5.489 ± 0.001 h.

Koronis family asteroids 1443 Ruppina, 1848 Delvaux, and 2144 Marietta were observed at Whitin Observatory in Wellesley, Massachusetts between 2014 February and April. The observations were made in order to determine the asteroids' *R* magnitudes and rotation periods, specifically in support of future spin vector determinations.

### Observations

Ruppina, Delvaux, and Marietta were observed for three nights over spans of 13, 18, and 40 nights, respectively, following the observing principles described by Slivan *et al*. (2008). Table I presents a summary of the observing circumstances. The images were taken on a 2048-pixel square back-illuminated CCD camera with a 2x2 binned e2v detector. The scale was 1.2 arc seconds per pixel using Whitin Observatory's 0.61-m Sawyer telescope. Lightcurve image integrations of 240 s were collected using an *R* filter. The *IRAF* software package was used for bias level and dark signal subtraction and twilight field flattening as well as for measuring instrumental magnitudes using synthetic aperture photometry. The standard uncertainties of the lightcurves, with respect to the on-chip comparison stars, were estimated from the RMS dispersion of the differential brightness of non-variable on-chip field stars of comparable brightness to the asteroid.

To determine *R* magnitudes, we used the simplified method for standard star calibration described by Binzel (2005) and Neugent and Slivan (2008). On one night of each object's lightcurve observations, we included a standard star from Landolt (1992). Prior to the observations, the "airmass plot calculator" application at the Web site *http://www.koronisfamily.com* was used to determine the times at which the asteroid and its comparison star were at the same airmass as the standard star.

### Analysis

To determine the rotation periods from on-chip differential photometry, light-time corrections were applied and then features were matched by inspection as described by Slivan *et al.* (2008). Each object's period estimate was then refined using a Fourier series model to the folded composite lightcurve shape including all data, while adjusting the nightly brightness zero points to best match the calibrated *R* lightcurves until the overall RMS residual was minimized. Our rotation period results are summarized in Table II, which lists the derived periods with their uncertainties. Amplitude ranges were calculated by using the brightness of the Fourier series model primary and secondary extrema.

## Results

The observing program reached its goals of independently checking the periods for Ruppina, Delvaux and Marietta. It also improved the previously determined period for Marietta. All three rotation periods are well within the wide range of values, 3 – 60 h, known of other Koronis family members (Slivan *et al*., 2008; Fig. 71). Figures 1-3 show the composite lightcurves for 1443 Ruppina, 1848 Delvaux, and 2144 Marietta respectively. The error bars represent the estimated one-sigma uncertainty with respect to the local comparison star used. Each graph spans a vertical scale of one magnitude. Nights of relative lightcurve data have been shifted in brightness for best fit to the standard *R* calibrated lightcurves.

1443 Ruppina. During the 2014 apparition of Ruppina, lightcurves were obtained between phase angles 3°-13°. Observations from UT February 26 spanned 6 hours, which allowed us to determine a rotation period of 5.880 h. Analysis of all three nights of data gathered over the 13-night apparition span determined a rotation period of 5.880 ± 0.001 h. This agrees with the previously determined period obtained by Neugent and Slivan (2008).

1848 Delvaux. We observed Delvaux on three nights during its 2014 apparition between phase angles 1°-4°. Data from March 7 spanned 4 hours, leading to a straightforward initial period determination of 3.639 h. Analysis of data from three nights yields a rotation period of 3.639 ± 0.001 h, which is consistent with the previously determined period from Slivan *et al.* (2008) as well as the unpublished values reported by Behrend (2004, 2011).

(2144) Marietta. Three nights of observations yielded a rotation period of 5.489 ± 0.001 h. This is consistent with the less precise previous measurement of a 5.489 ± 0.006 h made by Slivan *et al*. (2008), and significantly shorter than the provisional result reported by Behrend (2010). Marietta was observed at phase angles 4°-16° during its 2014 apparition.

The data for all of these objects eventually will be used for spin vector and shape modeling. In order to obtain reliable spin vector results, observations from at least five to six different viewing aspects need to be collected. Our images provide data for the second apparition of 1443 Ruppina, the sixth apparition of 1848 Delvaux, and the fifth apparition of 2144 Marietta in Dr. Stephen Slivan's Koronis family spin vector solution program.

## Acknowledgements

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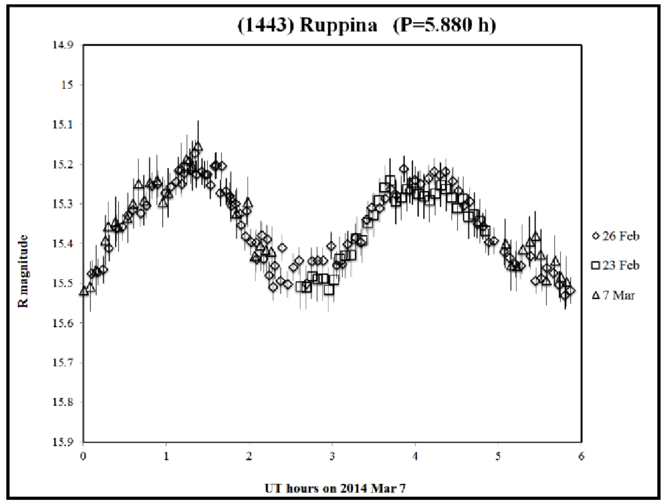


Figure 1. Composite lightcurve for (1443) Ruppina. The error in the photometric calibration to the standard R magnitude scale is ± 0.02.

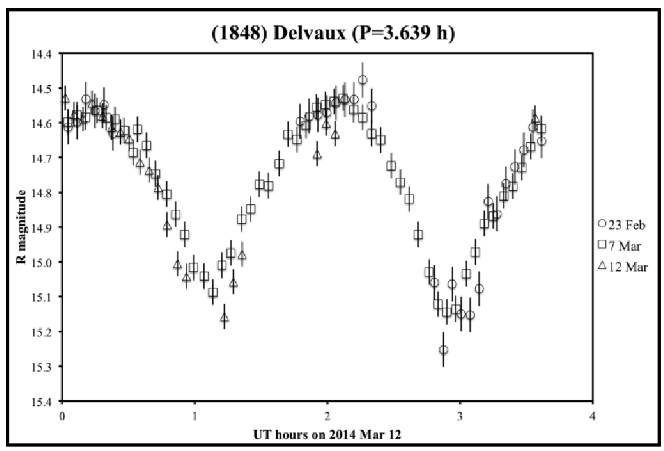


Figure 2. Composite lightcurve for (1848) Delvaux. The error in the photometric calibration to the standard R magnitude scale is ± 0.09.

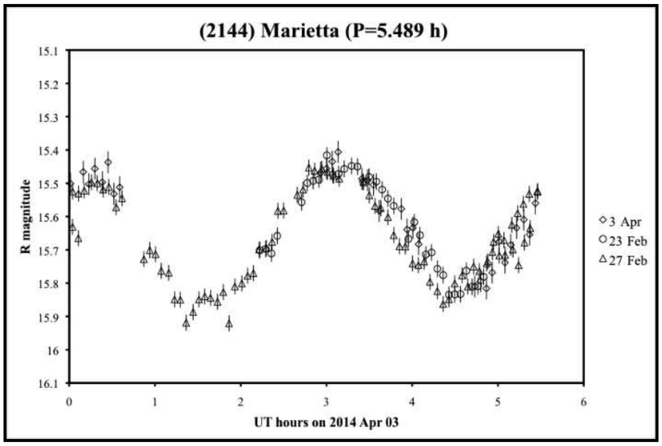


Figure 3. Composite lightcurve for (2144) Marietta. The error in the photometric calibration to the standard R magnitude scale is ±0.02.

| Asteroid | UT Date | λ (PAB) (°) | β (PAB) (°) | α(°) | Observer(s) |
|---|---|---|---|---|---|
| (1443) Ruppina | 23 Feb | 146.8 | -1.1 | 2.8 | Slivan, Yazdi |
| (1443) Ruppina | 26 Feb | 146.8 | -1.0 | 3.9 | Slivan, Hartt |
| (1443) Ruppina | 07 Mar | 146.7 | -1.0 | 7.1 | Hartt, Thayer |
| (1848) Delvaux | 23 Feb | 163.1 | -0.3 | 3.6 | Slivan |
| (1848) Delvaux | 07 Mar | 163.0 | -0.4 | 1.3 | Arredondo, Fendrock |
| (1848) Delvaux | 12 Mar | 162.9 | -0.4 | 3.3 | Arredondo, Thayer |
| (2144) Marietta | 23 Feb | 146.7 | 0.4 | 3.9 | Slivan, Yazdi |
| (2144) Marietta | 27 Feb | 147.5 | 0.4 | 5.5 | Yazdi, Blancato |
| (2144) Marietta | 03 Apr | 154.5 | 0.8 | 16.4 | Yazdi, Blancato |

Table I. Observing Circumstances. UT dates are in year 2014. λ and β are J2000.0 ecliptic longitude and latitude of the phase angle bisector respectively, and α is the solar phase angle.

| Asteroid | H | Synodic Period (h) | Amplitude (mag) |
|---|---|---|---|
| (1443) Ruppina | 11.40 | 5.880 ± 0.001 | 0.27-0.34 |
| (1848) Delvaux | 11.24 | 3.639 ± 0.001 | 0.49-0.62 |
| (2144) Marietta | 11.37 | 5.489 ± 0.001 | 0.32-0.42 |

Table II. Lightcurve period and amplitude results. Values for H given by Slivan et al. (2008). The subjective confidence code Q as used by Lagerkvist et al. (1989) is 3 “no ambiguity” for all three periods.

## PERIOD DETERMINATION FOR 398 ADMETE: THE LOWEST NUMBERED ASTEROID WITH NO PREVIOUSLY KNOWN PERIOD

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Lightcurve analysis for 398 Admete was performed using observations during its 2014 opposition. The synodic rotation period was found to be 11.208 ± 0.001 h and the lightcurve amplitude was 0.13 ± 0.02 mag.

398 Admete is a main-belt asteroid discovered in 1894 by Auguste Charlois in Nice (France). It appeared on the CALL web site as an asteroid photometry opportunity due to it reaching a favorable apparition in 2014 and having no defined lightcurve parameters.

Unfiltered CCD photometric images were taken at Observatorio Los Algarrobos, Salto, Uruguay (MPC Code I38) in 2014 from May 27 to July 7. The telescope was a 0.3-m Meade LX-200R reduced to *f*/6.9. The imager was a QSI 516wsg NABG (non-antiblooming gate) with a 1536x1024 array of 9-micron pixels and 23x16 arcminute field-of-view. The exposures increased from 120 to 210 seconds as the asteroid faded past-opposition (May 10). 2x2 binning was used, yielding an image scale of 1.77 arcseconds per pixel. The camera was set to –15° C and off-axis guided by means of an SX Lodestar camera and *PHD Guiding* (Stark Labs) software. Image acquisition was done with *MaxIm DL5* (Diffraction Limited). The computer was synchronized with atomic clock time via Internet NTP servers at the beginning of each session.

All images were dark and flat-field corrected and then measured using *MPO Canopus* (Bdw Publishing) version 10.4.3.16 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).

More than 85 hours of effective observation along 19 sessions and about 2,140 data points were required in order to solve the noisy and essentially flat lightcurve. Over the span of observations, the phase angle varied from 6.0º to 15.7º, the phase angle bisector ecliptic longitude from 231.0º to 230.8º to 231.9º, and the phase angle bisector ecliptic latitude from –8.4º to –6.9º. The rotation period for 398 Admete was determined to be 11.208 ± 0.001 h along with a peak-to-peak amplitude of 0.13 ± 0.02 mag. The period spectrum also showed another plausible solution at 22.4 h (twice the adopted period), although slightly mathematically worse than the chosen period. No clear evidence of tumbling or binary companion was seen in the lightcurve.

At the time of this study 398 Admete happened to be the lowest numbered asteroid for which no rotation parameters were found in the literature. For those numbered below 500, only one remains in such condition (457 Alleghenia), and from 501 to 1000, 22 still have no reported rotation period. This is a dramatic reduction from just two years ago (Alvarez, 2012). However, even in cases where