INITIAL RESULTS FROM A DEDICATED H-G PROJECT

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One of the main obstacles to studies of the asteroid population, NEAs in particular, is the lack of good H (absolute magnitude) and G (phase slope) values. Starting in early 2007, the Palmer Divide Observatory began a dedicated program for determining the H-G values for as many asteroids as possible. The initial efforts involved MBA asteroids as a control group where the results were compared to values given in the MPCORB file (MPC 2007). Subsequent observations will concentrate on brighter targets within the NEA and inner main-belt populations. A consequence of these observations is also the determination of the V-R color index for almost all targeted asteroids. This paper discusses the details of the project, from strategy to implementation, as well as reporting some initial findings.

Introduction

The H-G system of absolute magnitude and phase slope parameter was developed by Bowell et al (1989). The H value took on the meaning of being the Johnson V magnitude of a given asteroid when moved to unity distance from the Sun and Earth and viewed at 0° phase angle. The phase slope parameter (G) was defined so that it is a continuous function, even through very small phase angles, and is valid for phase angles up to approximately 120°.

When phase angles are <7°, the so-called "opposition effect" comes into play, causing the asteroid to brighten in a manner different from what pure geometry would dictate. The value of G models the behavior of the asteroid's brightness both well away from and near opposition. The smaller the value of G, the steeper the slope of the phase curve line. It is even possible for G to be negative, e.g., –0.04 for 163 Erigone. The value of G along with the behavior of the curve near opposition can be used to develop models that explain the opposition effect and general scattering laws. The latter come into play when inverting lightcurves, i.e., generating a shape and spin axis model based on a number of lightcurves.

In order to establish a valid value for G, one must have observations near opposition, i.e., when the phase angle is near as possible to 0°. If such observations are not available, e.g., most observations are at phase angles >7°, then a value for G must be assumed. This still allows a value for H to be found. The adopted default value for G is 0.15, though it has been shown that this is merely a compromise and that the actual value can be dependent on taxonomic class (see pg. 553 of Bowell 1989).

The determination of the H value of an asteroid has many direct ramifications. Chief among them is the determination of the approximate size of the asteroid based on the formula

$$\log D\ (km) = 3.1235 - 0.2H - (0.5 * \log(pv))$$

where H is the absolute magnitude of the asteroid and pv is the geometric albedo in the V band.

If not known directly, the albedo can be assumed based on the taxonomic class of the asteroid. A large number of such classifications are available using either the Tholen (1989) or SMASS II (Bus 2002) catalogs. Lacking a direct classification, the albedo can be assumed based on the orbit of the asteroid, e.g., following the method of Harris (2007) in which A and M orbit classes or main belt asteroids with a <2.6 AU are assumed to be Tholen "S" class with an albedo 0.18. Orbit classes C, T, K, or main-belt asteroids with a > 2.7 AU are assumed "C" or "D", with and albedo 0.058. Main-belt asteroids with a semi-major axis in the range 2.6-2.7 are classed "SC" and an albedo of 0.10 is assumed. Hungaria asteroids lacking any other taxonomic information are assumed to have an albedo of 0.30, intermediate between S and E classes.

Finding the H magnitude and value of G requires using the reduced magnitude of the asteroid at various phase angles. The reduced magnitude is the observed V magnitude converted to unity distance using

$$Vr = Vo - 5.0 \log(Rr)$$

where Vr is the reduced magnitude, Vo is the observed magnitude, R is the Sun-asteroid distance, and r is the Earth-asteroid distance, both in AU. The values for H and G are found using the algorithm described by Bowell and implemented in the FAZ program written by Alan Harris (see Bowell 1989). Figure 1 shows a plot of the reduced magnitude versus phase for 160 Una.

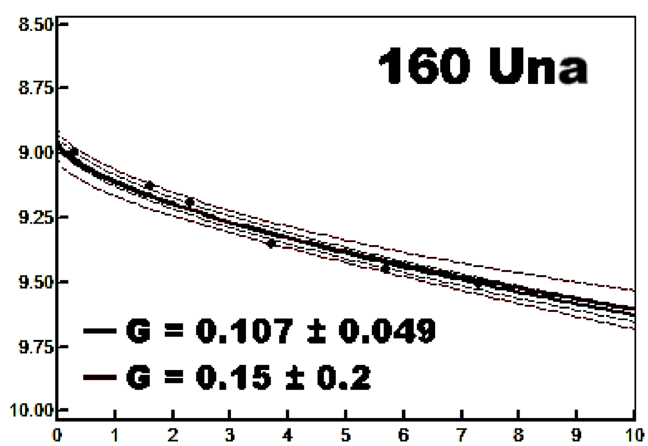

Figure 1. A plot of the reduced magnitude of 160 Una versus the phase angle. The slope of the line when the phase is >7° is the phase slope parameter, G. The value of H is the magnitude when the phase angle is 0°. Here H = 8.95 ± 0.02 and G = 0.11 ± 0.05.

The best results are achieved if, for a given night, the mean magnitude for the asteroid is used. This implies that the rotation period, amplitude, and phase at a given epoch are known. This is often not the case. It would be easy enough to follow an asteroid for several nights to obtain this information, but then the number of asteroids that could be covered during a given lunation would be reduced significantly. The problem can be overcome by getting numerous data points for the asteroid, e.g., every possible night over several weeks, and letting the amplitude variation "average out" over time (see pg. 550 of Bowell 1989).

Observation and Reduction Methods

All observations were made using a 0.35m Meade LX-200 GPS Schmidt-Cassegrain telescope and Finger Lakes Instrumentation CCD camera with a Kodak KAF-1001E chip (1024x1024x24m). The camera was run at –30°C and 2x2 binning (48m pixels), which gave a pixel scale of approximately 3.0 arcseconds. FWHM seeing is often around 6 arcseconds, so this scaling works for most cases. On exceptional nights, the camera was run a 1x1 binning (1.5"/pixel) but only the central 3/4 of the full frame was downloaded in order to increase throughput and conserve disc space. All images were guided using an external 80mm f/7 guide scope with SBIG ST-402. Guide exposures were fixed at 5 seconds using 1x1 binning to give maximum pixel scale and, therefore, guiding accuracy. A typical sequence involved shooting three images each in V and R, i.e., (VRVRVR), with the same exposure used for both filters. The exposures ranged from 90 to 180 seconds for targets of 10.5 to 14.5 V magnitude. A custom program was written to generate scripts used by MPO Connections (Bdw Publishing). That program automatically generated a multiplier that changed the exposure for each asteroid based on its predicted magnitude. Furthermore, the application kept track of which asteroids had been observed and the interval since the last observation. A report using this information formed the first step in generating the Connections script.

Depending on the length of the night, anywhere from 20 to 40 asteroids were observed. The observations started with the westernmost object and moved eastward, concluding at the start of twilight the following morning. At the start of a new lunation (third quarter to first quarter), a new set of asteroids was selected, those being east of opposition so that they could be followed for another two or three months. After the third lunation, the oldest set of asteroids was dropped from the list. A standard reference field (M67) was observed on several nights at the start of the program in order to determine the v-r to V-R transform. A new transform will be determined about every three to four months to assure the best possible accuracy and consistency. This transform allows a direct conversion of an instrumental v-r magnitude to the standard V-R as long as a good value for the first order v-r extinction (k'vr) is known (Warner 2006). It is not required to know the true values of k'v and k'r but only the differential value, k'vr. Furthermore, this value tends to be stable on a seasonal level, though occasional checks were made to assure this was the case.

For each night's observation of a given asteroid, the three V and R images were measured to find an average v-r value and standard deviation. This was converted to a V-R value with the total error being the standard deviation and error of the v-r to V-R transform added in quadrature. The final V-R value was found by using the Gaussian weighted average of the individual nights, using the aforementioned errors for the weighting and to determine the overall error.

The v instrumental magnitudes were converted to V using a modification of the method described by Binzel (2005) as modified by the author (Warner 2006). In general, the v-V magnitudes of several stars in the field, usually 5 to 10, were averaged to find a constant offset. The standard deviation of this average was also computed. Before computing the v-V value for each star in each image, the instrumental v magnitude was corrected for both first order extinction and V-R color index, thus reducing the values to instrumental exoatmospheric standard magnitudes. Since the value of air mass, X, was essentially identical for all stars and the target, the true value of k'v was not critical since any error would be absorbed into the v-V offset value. For computing the V-R color index, the critical factor was having a valid differential first order extinction, i.e, k'vr, to apply to the differential v-r magnitude. The v-V magnitude offset was then applied to the v instrumental magnitude of the asteroid, but only after the same corrections had been applied, i.e., those for first order extinction and V-R color index. The final result was the average V magnitude and standard deviation. This value was then stored along with the reduced V-R magnitude and error in the observations data base table for future calculations.

Converting 2MASS J-K Magnitudes to the BV(RI)c System

As noted above, field stars were used to derive the v-V offset for each night and field. Since asteroids move, the same comparison stars cannot be used over an entire lunation and, most times, not even on consecutive nights. Furthermore, asteroids are rarely so obliging as to wander through a Landolt or other well-calibrated field. While the best results would be obtained with all-sky photometry, that presents several problems, the foremost being that photometric nights are not that common at the PDO location.

Richard Miles (2005) developed a useful solution by working with Hipparcos catalog stars and using two guide scopes with CCD cameras simultaneously with the main scope. One guide scope shoots in V while the other shoots in I in order to determine the magnitudes and color index of field stars and asteroid as well as nearby Hipparcos stars. At the same time, the main scopes shoots in V or Clear. The guide scope images are used to find the necessary reduction values so that the main scope instrumental magnitudes can be converted to standard V magnitudes. While elegant in approach and implementation, it is more complex than was desired and required additional equipment (expense). Therefore, an alternate method was attempted.

Since there were already excellent conversion formulae available, it was first though that using the Sloan Digital Sky Survey catalog magnitudes converted to BV(RI)c would be practical but the sky coverage was too limited. The JHK magnitudes in the 2MASS catalog (Neugebauer & Leighton 1969) seemed a good second choice. The DVD version of the catalog was obtained and a set of conversion formulae was found. This involved using high-quality Landolt field stars that were included in the LONEOS catalog prepared by Brian Skiff (Skiff 2007). Any star with an uncertain identification or close companion was immediately rejected. Using that subset of about 300 stars, the corresponding star in the 2MASS catalog was found for each star in the subset. The 2MASS catalog includes several flags for each star that indicate the quality of the photometry or if the star had a close companion. If any flag indicated a problem with the J or K magnitude, that star was rejected. The final result was a set of 128 high-quality stars with BV(RI)c and J-K magnitudes.

The color-color plots show the results of comparing various combinations against J-K. It was immediately obvious that linear fits would not be ideal. Instead, third-degree polynomials were applied to find the conversion formulae. The J-K values were limited to a range of –0.1 to 1.0 in order to avoid excessively blue and, more important, red stars. Table 1 shows the final results for converting J-K to BV(RI)c magnitudes, including the correlation fit of the polynomial and the standard deviation of the errors. The latter were found by applying the conversion formula to find the appropriate value for a given star and then finding the difference between that computed value and the Landolt catalog value.

	$(J-K)^3$ C3	$(J-K)^2$ C2	(J-K) C1	Co	R	S.D.
B-J	1.7495	-2.7785	5.2150	0.1980	0.9934	±0.080
B-V	0.2807	-0.4535	1.7006	0.0484	0.9838	±0.034
V-J	1.4688	-2.3250	3.5143	0.1496	0.9936	±0.050
R-J	1.1230	-1.7849	2.5105	0.1045	0.9914	±0.040
V-R	0.3458	-0.5401	1.0038	0.0451	0.9877	±0.021
I-J	0.2963	-0.4866	1.2816	0.0724	0.9844	±0.034
V-I	1.0770	-1.6902	2.1652	0.0856	0.9913	±0.034

Table 1. Terms for converting J-K to BV(RI)c system and resulting errors. R is the correlation of the fit for the third-degree polynomial while S.D. is the standard deviation of the average of the errors when back-fitting the computed magnitudes to the Landolt standards.

This is not the first time such formulae have been found. For example, Caldwell et al (1993) used standard stars from several catalogs covering the southern sky, e.g., E and F regions, and applied ninth-order polynomials to find the conversion factors. Within the range of $-0.1 < J-K < 1.0$, the converted magnitudes based on this paper generally agree with those of Caldwell to 0.01 mag. Caldwell also found no need for separate formulae for dwarfs versus giants when converting J-K to the BV(RI)c system. This was not the case when converting color indices within the BV(RI)c system, e.g., V-I to V-R. There, separate formulae were definitely required. It should be noted that there may have been insufficient data to establish the need for separate formulae for the J-K conversions.

Using the derived formulae, a custom version of the 2MASS catalog was created that stores the converted BV(RI)c magnitudes. The restrictions placed on the stars, i.e., high-quality photometry and no confusing stars in both J and K magnitudes, produced about 300 M stars. Unfortunately, the density of coverage was not uniform and some fields were found lacking. Fortunately, the UCAC2 catalog (Zacharias 2004) also contains JHK magnitudes and (modified) photometry and confusion flags that allow converting the entries from that catalog as well. Although UCAC2 coverage does not extend to the North Celestial Pole, its coverage – especially when combined with the modified 2MASS catalog – is such that it's rare to have a field with less than five to seven stars with sufficient SNR available.

Effects of Interstellar Reddening

Because the 2MASS magnitudes are in the near-IR region, the effects of interstellar reddening cannot be ignored. The formulae were derived without correcting for reddening, i.e., they are based on the apparent J-K magnitude and not one that would be derived based on spectroscopic analysis. However, the reference fields were mostly in areas where interstellar reddening is not significant, and so the conversion formulae can be taken at face value.

One possible way to correct for reddening would be to locate stars of known solar color (from a spectroscopic catalog) near the target fields that are also in the 2MASS catalog. According to Pfau (1994), a color excess $E(B-V) = 1.0$ is equivalent to $E(J-K) = 0.54$. Using this, the 2MASS data and conversion formulae could then be used to determine the derived B-V and then E(J-K) via E(B-V). The corrected J-K magnitudes could then be used to find V-J instead of the actual catalog values. This does require having solar analogs nearby, which is not always likely, and is further complicated by the extreme non-uniformity of reddening near the galactic plane. Since the J-K relationships are based on, approximately, non-reddened J-K magnitudes, another possibility would be to compare the derived V-R magnitudes for field stars, which are derived from v-r and do not use the J-K relationship, against those computed from the J-K magnitude. Since the J and K magnitudes will be reddened less severely than those in v and r, the derived V-R magnitude will differ from the directly measured value. The differences could be used to establish a correlation that would provide corrected J-K magnitudes and, therefore, better V magnitudes. An investigation of this concept is planned, with results to be published at a later time.

Initial Results

During the first two months of the project, in early 2007, data were obtained on more than 50 asteroids. Of these, only ten had sufficient data near and away from opposition to derive what were considered to be acceptable values for the phase slope parameter (G). For the remaining asteroids, the value of G was held constant at 0.15 to determine H magnitudes. A minimum of two nights was required to find and report a derived V-R color index though most of those reported here had at least three. The results are shown in Table 2.

Columns 3 and 4 are the H and error found at PDO. Column 5 is the H value from the MPCORB data file (2007) while column 6 is the difference (PDO-MPC) between the two H values. Columns 7 and 8 are, respectively, the derived G and error values. Note that the error defaults to ±0.2 when assuming the default value of G. Column 9 is the derived V-R magnitude and column 10 is the error. Column 11 shows the minimum and maximum phase angles over which data were obtained. Column 12 is the number of nights on which data for the asteroid were obtained. The actual number of observations is greater than that since three images each were taken in V and R to obtain averages and standard deviations.

The first set of plots shows the data and derived third order polynomial for the J-K conversions. The second set of plots show the phase curves for those asteroids for which a G value other than the default was found. The plots show the phase curve and error envelope for both the new value of G and for the default value of G = 0.15.

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#	Name	H	HE	MPC	H-MPC	G	GE	V-R	V-R E	Phase Min/Max	N
17	Thetis	7.78	0.15	7.76	0.03	0.15	0.2	0.474	0.011	11.3,22.3	5
23	Thalia	7.45	0.13	6.95	0.50	0.15	0.2	0.363	0.041	7.9,9.9	3
31	Euphrosyne	6.74	0.21	6.74	0.00	0.15	0.2	0.447	0.008	18.2,22.4	4
36	Atalante	8.46	0.15	8.46	0.00	0.15	0.2	0.373	0.010	11.9,15.9	7
43	Ariadne	8.24	0.15	7.93	0.31	0.15	0.2	0.475	0.013	8.6,23.7	6
47	Aglaja	8.09	0.04	7.84	0.25	0.15	0.2	0.398	0.005	1.1,7.3	7
51	Nemausa	7.17	0.08	7.35	-0.18	-0.037	0.053	0.403	0.010	8.7,24.7	4
55	Pandora	7.93	0.09	7.80	0.13	0.15	0.2	0.411	0.010	6.1,9.1	4
61	Danae	7.56	0.10	7.68	-0.12	0.15	0.2	0.501	0.014	7.6,16.4	5
65	Cybele	6.58	0.06	6.62	-0.04	0.15	0.2	0.400	0.007	0.7,4.9	5
66	Maja	9.44	0.09	9.36	0.08	0.15	0.2	0.374	0.010	6.6,9.1	4
89	Julia	6.48	0.07	6.60	-0.12	0.005	0.064	0.468	0.005	6.7,17.7	5
93	Minerva	7.95	0.08	7.70	0.25	0.253	0.092	0.375	0.003	8.4,18.5	6
99	Dike	9.43	0.10	9.43	0.00	0.15	0.2	0.394	0.005	7.1,10.9	5
116	Sirona	7.67	0.07	7.82	-0.15	0.139	0.063	0.494	0.022	9.9,22.7	3
124	Alkeste	8.09	0.04	8.11	-0.02	0.317	0.054	0.530	0.014	7.4,20.3	5
142	Polana	10.28	0.12	10.27	0.01	0.15	0.2	0.361	0.004	1.8,24.4	4
148	Gallia	7.72	0.10	7.63	0.09	0.15	0.2	0.492	0.004	7.7,9.8	5
160	Una	8.95	0.02	9.08	-0.13	0.107	0.049	0.413	0.008	0.3,7.3	6
164	Eva	8.84	0.12	8.89	-0.05	0.15	0.2	0.395	0.006	10.0,13.8	3
165	Loreley	7.76	0.09	7.65	0.11	0.15	0.2	0.389	0.006	5.6,7.1	3
173	Ino	7.80	0.05	7.66	0.14	0.15	0.2	0.404	0.005	3.4,9.4	8
175	Andromache	8.06	0.06	8.31	-0.25	-0.230	0.059	0.366	0.004	6.0,13.4	5
190	Ismene	7.77	0.05	7.59	0.18	0.15	0.2	0.433	0.007	0.2,8.0	4
223	Rosa	9.72	0.04	9.68	0.04	0.15	0.2	0.400	0.027	2.4,5.4	2
287	Nephthys	8.26	0.07	8.30	-0.04	0.15	0.2	0.501	0.006	3.3,11.6	6
306	Unitas	9.06	0.10	8.96	0.10	0.15	0.2	0.487	0.007	2.4,21.4	5
316	Goberta	9.87	0.01	9.80	0.07	0.253	0.009	0.384	0.009	1.2,10.3	4
332	Siri	9.65	0.14	9.50	0.15	0.15	0.2	0.425	0.018	10.0,18.6	5
352	Gisela	10.22	0.11	10.01	0.21	0.15	0.2	0.517	0.006	6.4,23.8	4
363	Padua	8.88	0.06	9.01	-0.13	0.15	0.2	0.421	0.006	3.2,12.0	4
374	Burgundia	8.68	0.08	8.67	0.01	0.15	0.2	0.504	0.006	5.6,8.7	3
399	Persephone	8.91	0.11	9.00	-0.09	0.15	0.2	0.416	0.005	4.3,7.8	4
404	Arsinoe	9.11	0.18	9.01	0.10	0.15	0.2	0.372	0.005	13.5,25.6	6
412	Elisabetha	8.97	0.10	9.00	-0.03	0.15	0.2	0.406	0.003	7.9,9.2	6
442	Eichsfeldia	9.94	0.05	10.03	-0.09	0.300	0.095	0.378	0.004	3.8,9.0	6
449	Hamburga	9.79	0.07	9.47	0.32	0.15	0.2	0.382	0.003	3.6,7.7	4
471	Papagena	6.72	0.14	6.73	-0.01	0.15	0.2	0.503	0.018	11.0,14.7	6
481	Emita	8.66	0.09	8.60	0.06	0.15	0.2	0.376	0.004	4.9,9.8	5
490	Veritas	8.53	0.06	8.32	0.19	0.15	0.2	0.384	0.014	2.3,5.0	2
563	Suleika	8.63	0.13	8.50	0.13	0.15	0.2	0.501	0.003	8.7,21.0	5
579	Sidonia	8.07	0.07	7.85	0.22	0.15	0.2	0.478	0.008	5.1,6.6	4
604	Tekmessa	9.29	0.06	9.20	0.09	0.15	0.2	0.410	0.014	3.7,6.2	3
665	Sabine	8.61	0.11	8.10	0.51	0.15	0.2	0.434	0.027	9.0,11.8	5
675	Ludmilla	8.04	0.07	7.91	0.13	0.15	0.2	0.505	0.013	5.1,7.6	4
705	Erminia	8.31	0.16	8.39	-0.08	0.15	0.2	0.445	0.012	13.2,20.2	6
715	Transvaalia	10.07	0.09	9.80	0.27	0.15	0.2	0.403	0.009	7.6,9.6	3
720	Bohlinia	9.71	0.10	9.71	0.00	0.433	0.147	0.474	0.017	1.8,10.6	2
784	Pickeringia					0.15	0.2	0.416	0.023	3.9,6.7	2
803	Picka	9.53	0.05	9.60	-0.07	0.15	0.2	0.488	0.011	3.9,5.6	3
814	Tauris							0.402	0.011	7.8,8.8	2
818	Kapteynia					0.15	0.2	0.460	0.010	7.0,7.8	2
856	Backlunda	10.79	0.15	10.69	0.10	0.15	0.2	0.411	0.010	11.8,14.6	3
912	Maritima	9.21	0.08	8.40	0.81	0.15	0.2	0.390	0.005	6.9,9.6	8
924	Toni	9.45	0.15	9.37	0.08	0.15	0.2	0.424	0.011	6.6,15.6	2
927	Ratisbona	9.19	0.09	9.54	0.35	0.15	0.2	0.407	0.016	5.4,10.0	3
965	Angelica	10.08	0.19	9.80	0.28	0.15	0.2	0.386	0.005	17.1,22.2	4
1263	Varsavia	10.09	0.12	10.50	-0.41	0.15	0.2	0.434	0.035	7.1,14.9	2
1487	Boda	11.07	0.06	10.60	0.47	0.15	0.2	0.356	0.013	2.2,5.3	3
1884	Skip	12.51	0.23	11.70	0.81	0.15	0.2	0.491	0.032	17.8,27.5	3

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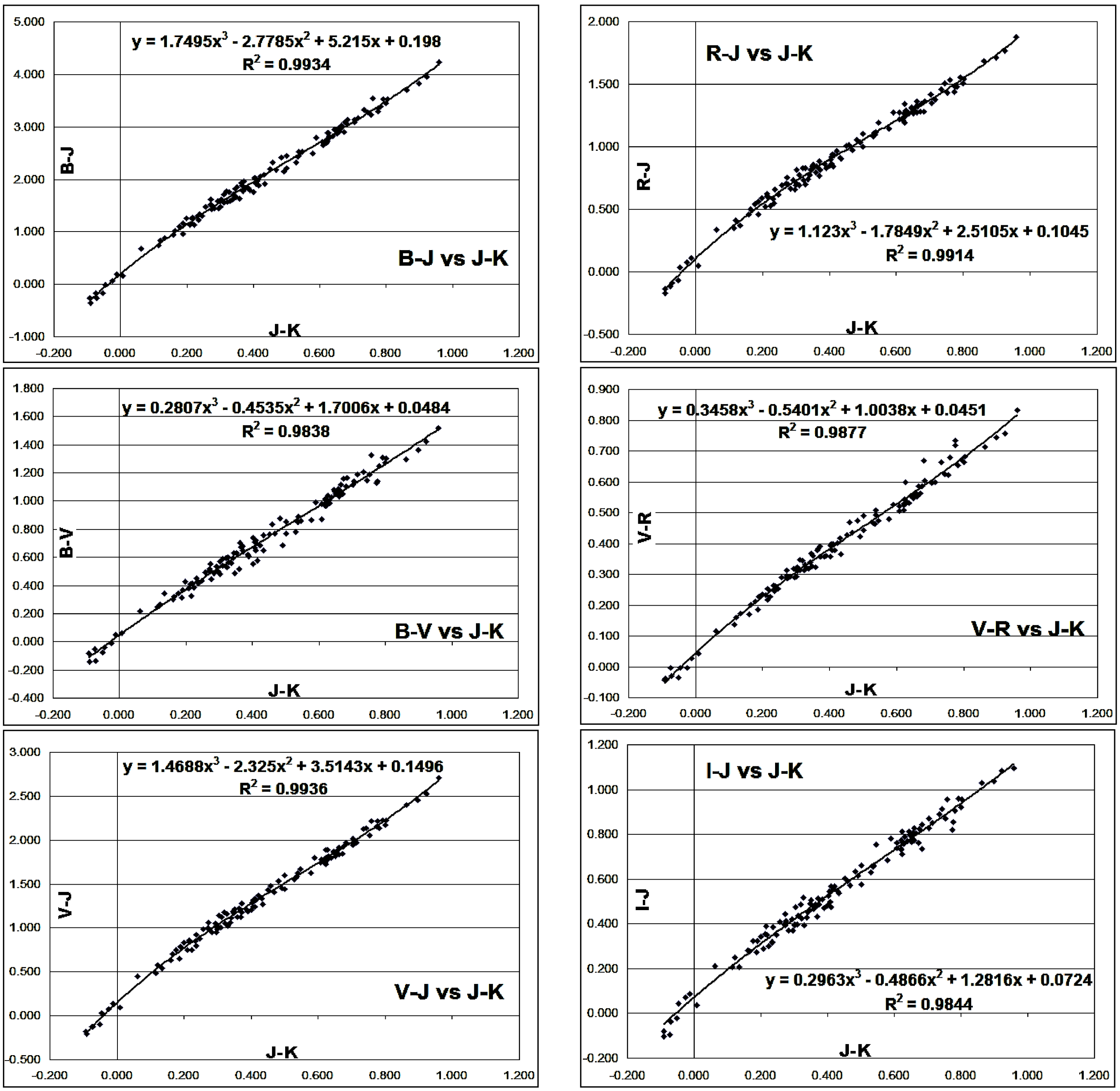

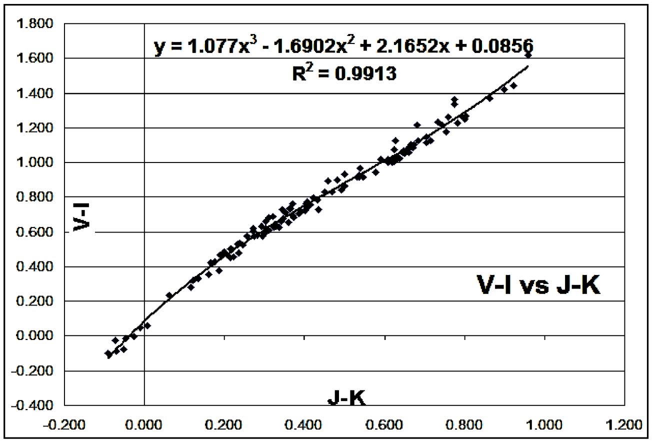
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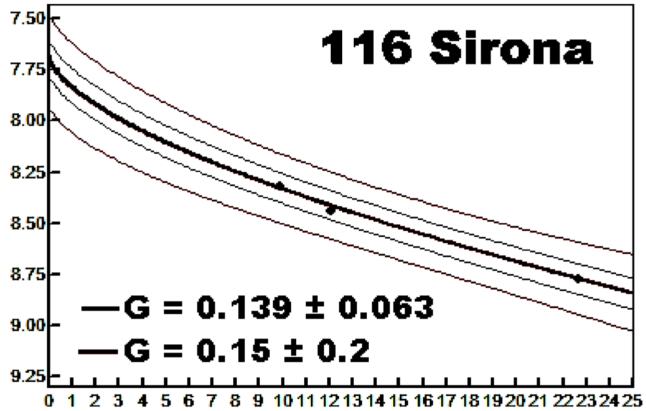
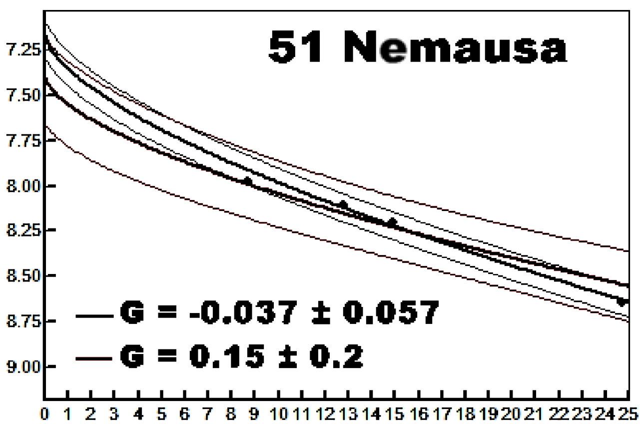
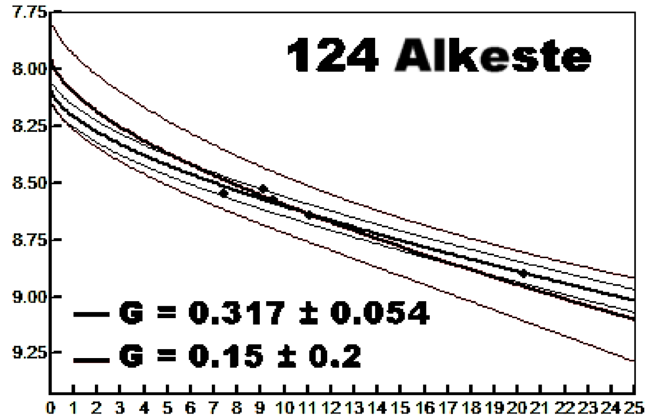
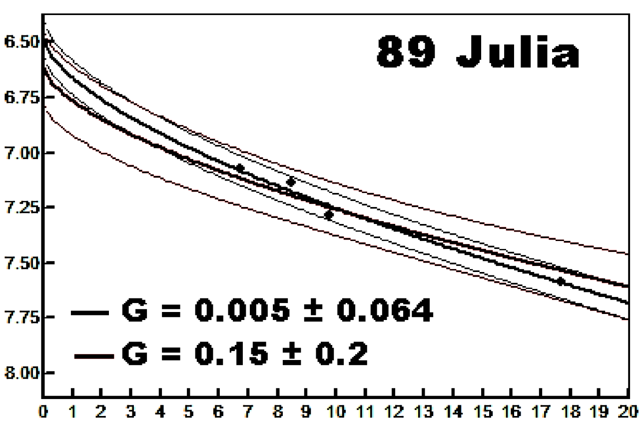
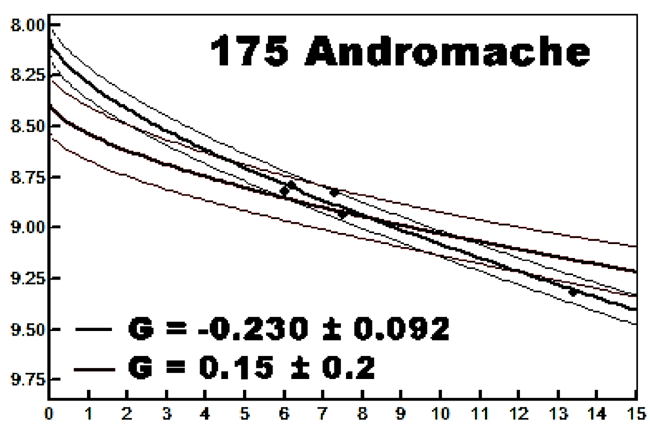
R² = 0.9913
V-I
V-I vs J-K
J-K


116 Sirona
G = 0.139 ± 0.063
G = 0.15 ± 0.2


51 Nemausa
G = -0.037 ± 0.057
G = 0.15 ± 0.2


124 Alkeste
G = 0.317 ± 0.054
G = 0.15 ± 0.2


89 Julia
G = 0.005 ± 0.064
G = 0.15 ± 0.2


175 Andromache
G = -0.230 ± 0.092
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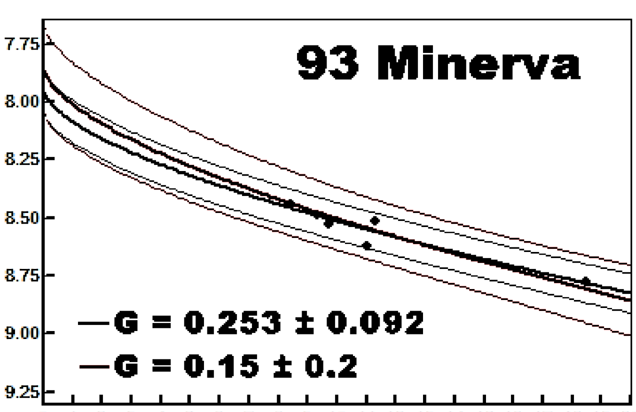
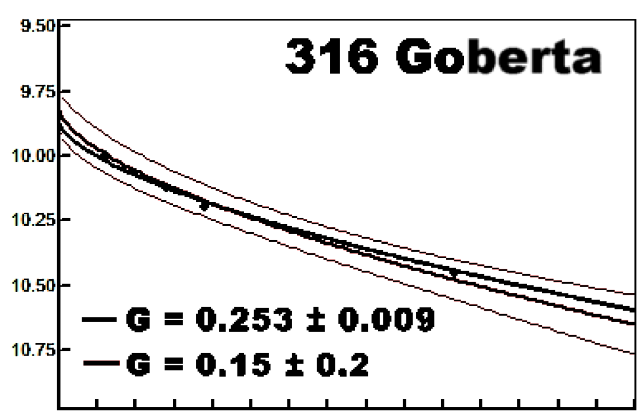
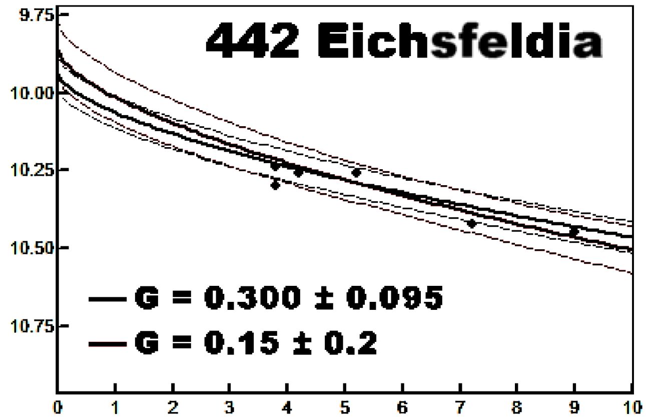
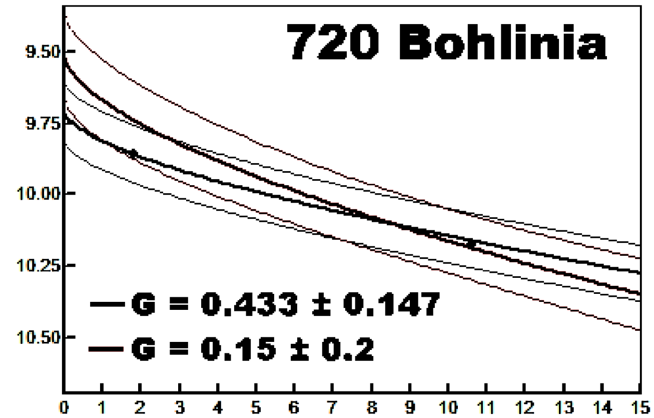

93 Minerva
G = 0.253 ± 0.092
G = 0.15 ± 0.2


316 Goberta
G = 0.253 ± 0.009
G = 0.15 ± 0.2





ASTEROID LIGHTCURVE ANALYSIS AT THE OAKLEY OBSERVATORY – MARCH/APRIL 2007

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Lightcurves for 24 asteroids were collected over six nights of observing during March and April of 2007 at the Oakley Observatory. The asteroids were: 234 Barbara, 279 Thule, 303 Josephina, 348 May, 621 Werdandi, 715 Transvaalia, 791 Ani, 1132 Hollandia, 1164 Kobolda, 1184 Gaea, 1385 Gelria, 1534 Nasi, 2341 Aoluta, 2582 Harimaya-Bashi, 2887 Krinov, 3166 Klondike, 3310 Patsy, 3451 Mentor, 3497 Innanen, 3575 Anyuta, 5484 Inoda, (7792) 1995 WZ3, (9873) 1992 GH, and (41577) 2000 SV2.

Twenty-four main-belt asteroids were observed over the course of six nights in March-April 2007. Twelve asteroids were observed on the nights of March 8 and 9, while another twelve were observed during April on the nights of the 17, 20, 21, and 22. The observations were taken from the Oakley Observatory at Rose-Hulman Institute of Technology in Terre Haute, Indiana. From the data that were collected, we were able to find lightcurves for 18 asteroids. Out of the 18 lightcurves, five were reasonably close to previously published periods, two differed significantly from previous results, and 11 were previously unrecorded results.

For the six nights of observing, three telescopes were used. Each telescope was a 14-inch Celestron optical tube assembly mounted on a Paramount ME. One telescope used an Apogee AP-8p camera. This CCD was unfiltered with an image scale of 2.00 arcseconds per pixel. The other two telescopes used SBIG STL-1001E cameras with a clear filter. One telescope had an image scale of 1.94 arcseconds per pixel while the other had an image pixel scale of 2.24 arcseconds per pixel. The exposure times varied from two to four minutes. Calibration of the images was done using master twilight flats, darks, and bias frames. All calibration frames were created using MaximDL and the images were calibrated using CCDSoft. MPO Canopus was used to measure the processed images.

Selection of asteroids was based on their sky position about one hour after sunset. Asteroids without previously published lightcurves were given higher priority than asteroids with known periods, but asteroids with uncertain periods were also selected in the hopes that we would be able to validate previous results.

As far as we are aware, these are the first reported observations for the period of the following asteroids: 715 Transvaalia, 791 Ani, 2341 Aoluta, 2582 Harimaya-Bashi, 2887 Krinov, 3166 Klondike, 3310 Patsy, 3451 Mentor, 3575 Anyuta, 5484 Inoda, and (41577) 2000 SV2. No repeatable pattern was found for the following asteroids: 234 Barbara, 279 Thule, 303 Josephina, 1184 Gaea, 1385 Gelria, or (7792) 1995 WZ3. This was due to noisy data and a less-than-ideal number of data points.

All results are listed in the table below. Comments have been included if they were necessary.

348 May. Our data gives a derived period matching the period given by Behrend (2006).

621 Werdandi. While the data seem to indicate a period that is different than that of Almeida, et al. (2004), the small number of data points that we have means our result may be incorrect.

1132 Hollandia. Although our data are somewhat noisy, it agrees fairly well with the reported period in Behrend (2006).

1164 Kobolda. Our result agrees with the period 4.141 ± 0.002 h given by Higgins and Oey (2007).

1534 Nasi. Our data are a little noisy, but they don't appear to agree with De Sanctis, et al. (1994)

3497 Innanen. Our result is close to the period 7.310 ± 0.001 h given by Fleenor (2007).

(9873) 1992 GH. The data are fairly noisy, but they support the period reported by Warner (2007).