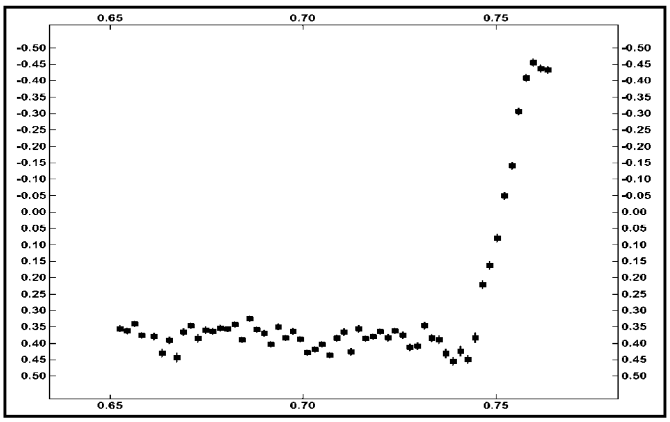
rotation rate? The first part does wonders for building up what I call "Spousal Permission Units" – good will credits saved for a future time when one needs to ask for a particularly big favor or have a transgression overlooked. I like to say that my wife, a professional violist, is now also a "rock star." That gets a few more SPUs.

In July, there was the spectacular fireworks show on Comet Temple$_1$ after the Deep Impact probe hit it. Unfortunately, the comet was too low in the sky for me to turn my scopes on it and so I had to rely on accounts from friends around the world. Jerry Foote in Kanab, UT, sent me an amazing image showing the plume of material coming from the nucleus. Bob Koff of Bennett, CO, sent me a lightcurve he generated from his observations.



Lightcurve of Comet Temple1 at impact. Bob Koff, Antelope Hills Observatory, Bennett, CO.

That's good work for something less than 20° above the horizon. Many of those observing visually reported they didn't notice much of a difference. The CCD camera does not lie! Data are still pouring in and no doubt there will be plenty to fuel theories and papers for years to come. This brought back memories of the Shoemaker-Levy 9 collision with Jupiter. That I *did* get to see, or at least the aftermath: a large "black-eye" in the Jovian clouds. It is one of the astronomical events my wife remembers most, along with comets Hale-Bopp and Hyakutake.

So, just when things seem a little routine and there's seemingly nothing new going on, along comes a good meeting of the minds and another spectacular space probe event to keep things interesting. Of course, there's always trying to keep up with Spirit and Opportunity on Mars, Cassini around Saturn, and data mining on-line databases – among just a few other things. Almost all of this didn't require collecting a single photon of my own. It's a good thing, too. A very uncooperative Mother Nature brought my observing to a near standstill this summer. That candy store had a very thick window keeping me from the real treats.

Clear (and interesting) Skies!

A SIMPLIFIED METHOD FOR STANDARD STAR CALIBRATION

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Calibration of asteroid lightcurves to the standard magnitude system is often lacking due to the perceived difficulty. However, reasonably good calibration can be achieved through a simple method if standard star choices and measurements are made strategically. Using standard stars matching asteroid colors and performing calibration measurements at similar airmass values reduces the effects of most correction terms, allowing much simplification in the reductions.

[Preamble: The method described here has been long utilized by experienced practitioners. As the method is self-apparent, it is seldom described. The description offered here is hoped to be useful to new observers.]

CCD imaging provides a powerful technique for measuring asteroid lightcurves through differential photometry between the asteroid and comparison stars in the same image. One of the advantages of this simultaneous recording of the asteroid and the comparison stars is that lightcurve measurements can be obtained on nights that are less than perfect. Even if good conditions are present, there is a perceived difficulty in obtaining absolute photometric calibration on the standard magnitude system. The apparent difficulty in calibration often arises because no filter is used within the system, where either none is supplied with the CCD or the object being measured is near the limit of detection and the maximum photon counts are necessary for the best possible lightcurve precision. In other instances, absolute photometric calibration is not obtained because of the perceived time and effort required to determine extinction coefficients and color correction terms for the CCD and its filter combinations.

The purpose of this article is to describe a simplified method for quickly obtaining a reasonable photometric calibration of CCD lightcurves with respect to the standard magnitude system. Indeed, precise absolute calibration to 0.01 magnitude or better is an art form requiring the dedication of a substantial amount of observing time and painstaking reductions so that one derives first and second order extinction terms for the night(s) of observations as well as the color correction terms for their CCD system and filters. However, with some careful planning of the standard star measurements all of these effects can be minimized to the point of being "ignorable" if absolute calibration to within several percent (0.05 magnitude) is acceptable. For most asteroids, this level of precision is sufficient to substantially improve their catalogued magnitudes, where uncertainties of many tenths of a magnitude are pervasive.

There are three observational precepts for performing simplified calibrations of CCD lightcurves that require some advance planning and at least uniform sky conditions (if not 'photometric' conditions) over the time interval of the calibration measurements: **(1)** Determine the time(s) of night when you can measure the asteroid and known standard stars at the same airmass.

(2) Choose standard stars having 'asteroid-like' colors.

(3) Obtain all of your asteroid and standard star calibration measurements in the same filter (V or R) as simultaneously as possible, where these filter measurements are well bracketed and linked to "routine" points as normally measured in the lightcurve. In some cases, the calibrations may even be performed using no filter at all.

To satisfy the first two observational precepts, my personal preference has always been to use standards from Landolt (1983). [Warner (2003) also provides a Landolt list and finder charts.] These standard stars are grouped at hourly intervals of right ascension and are located along the celestial equator, thus accessible to both northern and southern hemisphere observers. For the first precept, in the case where your target transits at a higher altitude (lower airmass) than the standard stars:

1a) Determine the airmass value for a star on the celestial equator when it crosses the meridian of your observatory. For most mid-latitudes, this is an airmass value around 1.3.

1b) Determine the time(s) when the asteroid you are observing will be at this airmass.

1c) Determine which Landolt standard star group(s) will be closest to the meridian at the time(s) determined in the preceding step.

In the case where the asteroid target transits at a greater airmass than the standards, e.g. a northern hemisphere observer tracking an object below the celestial equator, the first set of steps becomes:

1a) Determine the airmass value for your target asteroid when it crosses the meridian of your observatory.

1b) Determine the time when the target asteroid transits the meridian of your observatory.

1c) Determine which Landolt standard star group(s) will also be at this same airmass when your target object transits.

A very useful tool to do this automatically has been developed by Dr. Stephen M. Slivan (MIT). See the 'Airmass plot calculator' available at www.koronisfamily.com.

Once you have determined which group of Landolt stars can satisfy the first precept, you must make further selections to satisfy the second observational precept:

2) Select 2-5 Landolt stars within this group that have the best match to 'asteroid colors.' (Depending on the field of view of your system, many Landolt stars may be imaged simultaneously.) The stars you utilize for your calibration should have V-R magnitudes within the range of 0.3 to 0.6, or as close as possible to this range. (The Sun has V-R=0.36 in the Kron-Cousins system used by Landolt, and most asteroids are similar in color, or slightly redder, giving asteroids similar or slightly larger V-R values.) As noted above, the purpose of picking standard stars similar in color to the asteroid is so that second-order color correction terms may be reduced as much as possible. For the method described here, these color terms are ignored completely. Thus the closer the match between the asteroid and standard star colors, the lower the overall calibration error that is introduced by ignoring the color correction terms.

What filter to use for your calibrations: V or R? Because absolute 'H' magnitudes for asteroids are based on the V magnitude system, the V filter is preferred. However, choose V for your calibrations only if you can achieve sufficient precision (0.05 mag. or better) in your instrumental magnitudes so that the uncertainty in your asteroid measurement is the same or smaller than the errors introduced by this simplification method. If you cannot achieve 0.05 mag. or better precision with the V filter, use R. If your object is too faint for 0.05 magnitude precision in R, then no filter at all (!) remains a viable option. The method should still work under the assumption the standard star colors match the asteroid, although in practice the precision is unlikely to be better than 0.10 mag. As noted above, this can still provide an improvement in many cases to the catalogued magnitude values for asteroids.

Having chosen the filter (or no filter) for your standard measurements, satisfying the third observational precept is the most fun – as this is where you get to work fast and work smart (or at least program your sequences to work smart) at the telescope. The steps given below assume a calibration to V (for ease of description) and that most of your *lightcurve* measurements are being made with a clear filter (or no filter) – as this is the way to achieve the best precision for individual points in a lightcurve. If your lightcurve is in the same filter as your calibrations, simply ignore the references to the 'clear' filter. Similarly, substitute 'R' in place of the 'V' filter, if using R.

3a) As the asteroid approaches to within 0.1 (or less) of the 'magic' airmass equal to that of your standard star field, begin to alternate lightcurve imaging measurements between the clear (c) and V filter. For example: cVcVcVc brackets the V measures within the routine lightcurve. Bracketing around the V measurements is very important.

3b) With the standard star field(s) now at the same (or within 0.1) airmass of the asteroid field, image the standard star field(s) in V. Take 3-5 exposures of sufficient integration time to achieve 0.01 instrumental magnitude precision within each exposure.

3c) Repeat steps **3a** and **3b** again, if the airmass remains within about 0.1 between the standard field and the asteroid. Otherwise, resume your regular lightcurve imaging routine. [Of course, if the standard star field(s) reach the 'magic' airmass before the asteroid, step 3b can and should precede 3a].

Reduction Step 1: Reduce your lightcurve relative to on chip comparison stars in the usual way. The only difference to your regular reduction procedure is to pay special attention to the lightcurve data points that bracketed your V filter measurements in observational step 3a. Let $<\Delta M>$ denote the average relative magnitude of these bracketing lightcurve data points, as plotted within your normally reduced lightcurve.

Reduction Step 2: For each standard star image, compute the value $V_s - v_s$, where V_s is the standard magnitude from the Landolt list and v_s denotes the measured instrumental magnitude of the star in the V filter image. For all of your chosen standards, compute the average of all individual $V_s - v_s$ measures. Denote this average as $< V_s - v_s >$.

Reduction Step 3: Calculate the instrumental magnitude, v_a, of each V filter measurement of the asteroid taken in observing step 3a, and denote their average as $< v_a >$.

Reduction Step 4. Using the results of reduction steps 2 and 3, compute the V magnitude of the asteroid, call it V_a, from: $V_a = < v_a > + < V_s - v_s >$. This value of V_a is an anchor point connecting your lightcurve to the V magnitude system.

Reduction Step 5: Use the results of reduction steps 1 and 4 to calculate: $Z = V_a - <\Delta M>$. The value of Z is the vertical shift needed to place your lightcurve on the standard system. For example: suppose $V_a = 14.60$ and $<\Delta M> = +0.25$ (note the algebraic sign of $<\Delta M>$ is very important, and shown here explicitly). Then: $Z = 14.60 - (+0.25) = 14.35$. Adding the vertical shift value of Z to every relative magnitude value in your lightcurve places your lightcurve on the standard magnitude system. In this example, the bracketing clear filter measurements from observing step 3a, which give an average value $<\Delta M>$ of +0.25 in the relative magnitude, serve as the anchor. In the final calibrated lightcurve plot, these data points reside at a V magnitude of 14.60.

The overall success and precision of this simplified approach is dependent upon on how closely each of the three observing precepts is followed. It is worth emphasizing that this method, as described, makes an implicit assumption that sky conditions are uniform. Obviously the better the photometric conditions, the better the result. One worthwhile check is to plot comparison star instrumental magnitudes versus air mass, where a linear relationship confirms the constancy of the night – particularly at the time of standard star calibration. Additional steps that add increasing complexity (with the benefit of improving the precision) include the assumption of some nominal extinction coefficient (say 0.1 magnitude/airmass or other value typical for your site) so that all of your measurements in observing step 3 have first order extinction removed as a source of error. (This also reduces some of the time pressure to make all measurements simultaneously at the same airmass.) Obtaining clear (c) filter images of the standard stars, so that $(v_s - c_s)$ instrumental colors of the standards can be compared with the $(v_a - c_a)$ instrumental color of the asteroid, may constrain the choice of standard stars to those that are most 'asteroid-like', reducing unknown color correction terms. Likewise, the scatter or trend revealed by making a plot of calculated standard star V_s - v_s values versus their V-R catalogue values can reveal a color term for your photometric system, or at least give a good indication of the overall precision you have likely achieved in your calibrations.

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES OCTOBER-DECEMBER 2005

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We present here three lists of "targets of opportunity" for the period 2005 October – December. The first list is those asteroids reaching a favorable apparition during this period, are <15m at brightest, and have either no or poorly constrained lightcurve parameters. These circumstances make the asteroids particularly good targets for those with modest "backyard" telescopes, i.e., 0.2-0.5m.

The goal for these asteroids is to find a well-determined rotation rate, if at all possible. Don't hesitate to solicit help from other observers at widely spread longitudes should the initial finding for the period indicated that it will be difficult for a single station to find the period. This could be for the fact that the period has a multiple almost exactly equal to the interval between observing runs or the period is long, i.e., 18 hours to several days.

The Low Phase Angle list includes asteroids that reach very low phase angles. Getting accurate, calibrated measurements (usually V band) at or very near the moment of opposition can provide important information for those studying the "opposition effect", which is when objects near opposition brighten more than simple geometry would allow.

With current methods under common use, it's required to get several lightcurves spread from different apparitions in order to generate a model of the asteroid. The final list is those asteroids needing only a small number of lightcurves to allow Kaasalainen and others to work on a shape model.

We encourage anyone doing lightcurve work to publish their results in the *Minor Planet Bulletin* and, if nothing else, make the data available on a personal website. Previous issues have covered larger upload sites such as OLAF, SAPC, and the ADU. For more information about those sites, please contact Warner at the email address given above.