The BAA Observers' Workshops

The H and G magnitude system for asteroids

This article is based on a presentation given at the Observers' Workshop held at the Open University in Milton Keynes on 2007 February 24. It can be viewed on the Asteroids & Remote Planets Section website at **http://homepage.ntlworld.com/roger.dymock/index.htm**

When you look at an asteroid through the eyepiece of a telescope or on a CCD image it is a rather unexciting point of light. However by analysing a number of images, information on the nature of the object can be gleaned. Frequent (say every minute or few minutes) measurements of magnitude over periods of several hours can be used to generate a lightcurve. Analysis of such a lightcurve yields the period, shape and pole orientation of the object.

Measurements of position (astrometry) can be used to calculate the orbit of the asteroid and thus its distance from the Earth and the Sun at the time of the observations. These distances must be known in order for the absolute magnitude, H and the slope parameter, G to be calculated (it is common for G to be given a nominal value of 0.015). Knowing H and G, the visual magnitude can be calculated for any date. The diameter of the asteroid can be calculated from H if the albedo is known or a value is assumed.

The H-G magnitude system was developed for the purpose of predicting the magnitude of an asteroid as a function of solar phase angle. It also allows comparison of the brightness of an asteroid at different apparitions. This is necessary for studies of asteroid shapes and pole positions. The H-G magnitude system was adopted by the International Astronomical Union in 1985.

Definitions

Apparent visual magnitude, V: the magnitude of an asteroid when observed and measured visually or with a CCD camera employing a suitable method to extract V.

Reduced magnitude, H(α): V with the influence of distance removed, i.e. relating solely to the phase angle α. It assumes that the asteroid is 1 AU from both the Sun and the Earth and is calculated using the equation $H(\alpha) = V - 5\log(r\Delta)$, where:

$V =$ observed magnitude
$r =$ distance of the asteroid from the Sun
$\Delta =$ distance of the asteroid from the Earth
$\alpha =$ phase angle (Sun/Asteroid/Earth angle)

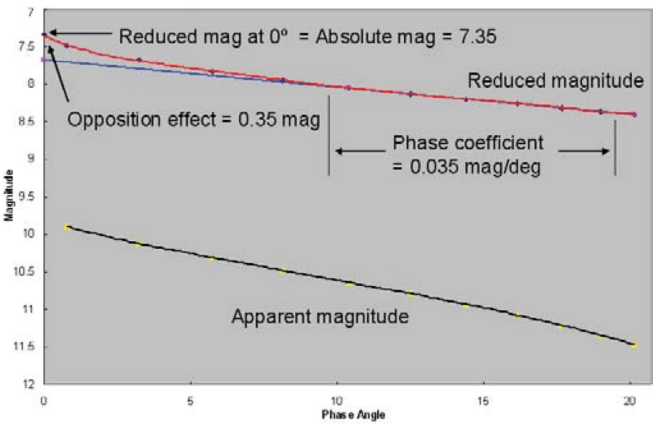

Figure 1. Effect of phase angle on magnitudes.

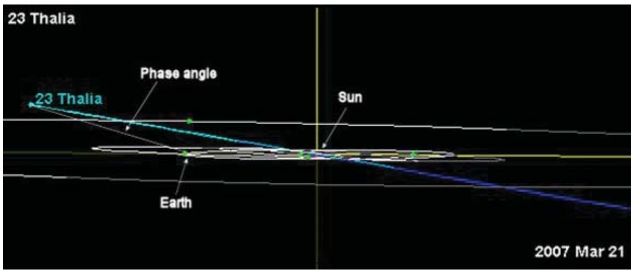

Figure 2. The inclined orbit of (23) Thalia at opposition.

Absolute magnitude, H: the V-band magnitude of an asteroid if it were 1 AU from the Earth and 1 AU from the Sun and fully illuminated, i.e. at zero phase angle (actually a geometrically impossible situation). H can be calculated from the equation

$H = H(\alpha) + 2.5\log[(1-G)\phi_1(\alpha) + G\,\phi_2(\alpha)]$, where:
$\phi_i(\alpha) = \exp\{-A_i(\tan\tfrac{1}{2}\,\alpha)^{B_i}\}$
$i = 1$ or 2, $A_1 = 3.33$, $A_2 = 1.87$, $B_1 = 0.63$ and $B_2 = 1.22$
and α is the phase angle in degrees.

Thus at zero phase angle and with $r = \Delta = 1$ AU, $H = H(\alpha)$. The various magnitudes mentioned above are average values as the instantaneous value can vary typically by 0.5 magnitudes due to the rotation of the asteroid. The equation for calculating absolute magnitude is not valid for phase angles greater than 120° and is best used at much smaller values, i.e. 20° or less.

Slope parameter, G: relates to the opposition effect. This is a surge in brightness, typically 0.3 magnitudes, observed when the object is near opposition. Its value depends on the way light is scattered by particles on the asteroid's surface. It is known accurately for only a small number of asteroids, hence for most asteroids a value of 0.15 is assumed.

Geometric albedo: ratio between the brightness of a planetary body, as viewed from the Sun, and a white, diffusely reflecting sphere of the same size and at the same distance. Zero for a perfect absorber and 1 for a perfect reflector. An asteroid's albedo cannot be used to predict G as all asteroids with similar albedos do not have similar surfaces.

Phase curve: a graph of reduced magnitude vs phase angle.

Phase coefficient, β: the slope of the linear portion of the phase curve, between 10° and 20° of phase.

These definitions are summarised graphically in Figure 1.

Not quite absolute

Unlike a star, the absolute magnitude of an asteroid and the slope parameter can have more than one value, and thus the quoted values are usually an average over several oppositions. The value of absolute magnitude can be affected by the position of the object's rotational axis, for example we may see a typically egg-shaped asteroid end-on at one opposition and side-on at another. H for (1) Ceres was ascertained in 1990 as 3.29; 1991, 3.31; and 1992, 3.39, giving a mean value of 3.33.

Targets

Ideally the asteroid to be observed or imaged should be within 20° of its opposition point and have a minimum phase angle of less

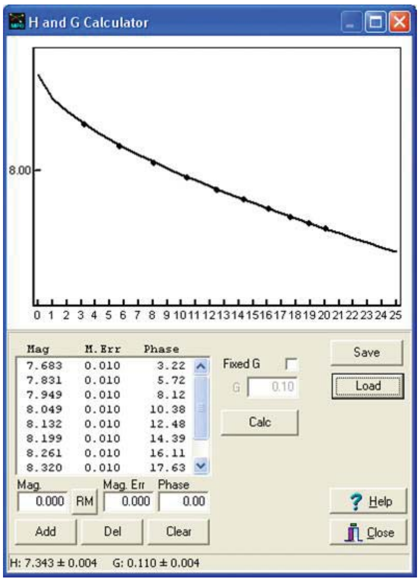

Figure 3. Phase curve and H & G values from **Canopus.**

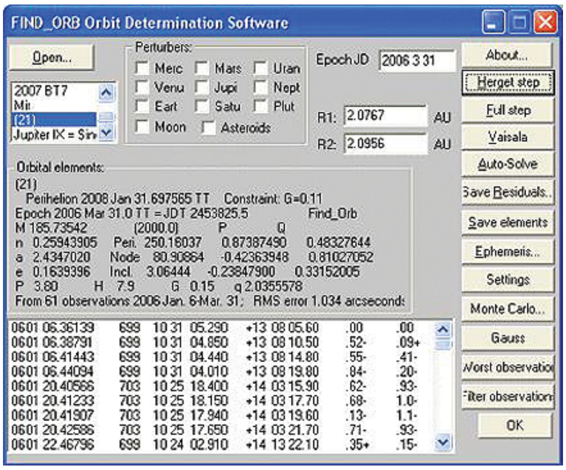

Figure 4. Output of FINDORB from **Project Pluto.**

than 1°. A list of suitable asteroids can be found in the BAA *Handbook*. Not all asteroids pass through zero degrees phase angle at opposition. For example Thalia's minimum phase angle was 7.8° at its 2007 opposition due to the high inclination of its orbit, as shown in Figure 2.

The Magnitude Alert Project at **http://home.earthlink.net/~lgasteroid/** is run by the Minor Planet Section of the US-based Association of Lunar and Planetary Observers. Its goal is to obtain improved estimates of absolute magnitudes of asteroids. A list of asteroids in need of observation can be found at **http://astrosurf.com/aude/map/MAPast.htm**. MAP alerts are also issued for specific asteroids.

Analysis

Analysis of observations is made easier by the availability of several software packages.

Canopus, by Brian Warner, at **http://www.minorplanetobserver.com/MPOSoftware/MPOCanopus.htm**, is a commercial package used primarily for generating lightcurves, but it also includes a utility for calculating H and G. A typical screen shot showing data input, the resulting phase curve and calculated H and G values is shown in Figure 3.

FAZ, by Alan Harris, is a DOS program for calculating H and G available from the ARPS Director.

CODES (Comet/Asteroid Orbit Determination and Ephemeris Software), by Jim Baer at **http://home.earthlink.net/~jimbaer1/** allows orbits, H, G and the asteroid's diameter (given a suitable value for its albedo) to be calculated from a set of astrometric and photometric observations.

FINDORB, from Project Pluto at **http://www.projectpluto.com/find_orb.htm** calculates orbital elements, ephemeris and H and G from observations in MPC format. Figure 4 shows the result of inputting data from the AstDys website at **http://hamilton.dm.unipi.it/cgi-bin/astdys/astibo.**

Conclusion

Deriving absolute magnitudes has something to offer for visual observers and CCD imagers, as well as armchair observers who just like to experiment with available data.

Ascertaining magnitude values from CCD images is no simple task. However the availability of the Carlsberg Meridian Catalogue, CMC14 at **http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=I/304** may make this task much easier. ARPS Assistant Director (Photometry) Richard Miles has devised a method of obtaining the V magnitude of an asteroid from a single image and this is presently being validated. Should the methodology be proven then a paper will be written for the *Journal* and posted on the ARPS website.

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