Determination of Limiting Magnitude of Natural Satellite Search (ALG-AP-003b)

Authors:

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History:

o 2013-Jul-30 - Draft

o 2013-Nov-05 - Baseline

o 2016-Mar-28 - Minor modifications

Description:

Extracted point sources in an OCAMS Natural Satellite search image will be matched with known stars in an astrometric/photometric stellar catalog (catalog UCAC4). A zeropoint magnitude in the V band will be determined for the field. The measured V magnitude and catalog V magnitude for each star will be determined and archived as well as the X-Y pixel and J2000 RA/DEC coordinates. The limiting magnitude will be determined for S/N of 2 across each field observed as part of the 1-m and 10-cm natural satellite searches. The limiting magnitude at each S/N level will be converted to minimum detectable diameters of natural satellites assuming an albedo of 0.03. These results will be plotted relative to spatial distance from Bennu.

Parameters:

infile – List of all sources detected within OCAMS natural satellite search fields; including their linkages with known stars in astrometric/photometric star catalogs, stellar V magnitudes, SPICE kernels (SPK for s/c and Bennu)

outfile – List of the V magnitudes of background stars detected at SNR of 2, 5, and 10 for all entire image natural satellite search images

Algorithm equations:

Three software packages will be used in the production of the limiting magnitude map: Astrometrica, Microsoft Excel and a COTS plotting package.

The Astrometrica software has been used for ~20 years to support ground-based astronomical observations of asteroids, comets and stars. As a COTS product, it is one of the primary tools used by asteroid observers. The software was also used by the NASA Dawn mission in support of their search for natural satellites around the asteroid Vesta (McFadden et al. 2016). The algorithms used by Astrometrica for the detection of stellar objects have been tested and proven over ~20 years of asteroid and variable star work. Microsoft Excel will be used to organize and modify the natural satellite search stellar photometric data. The COTS plotting software will be

used to create the plot of limiting magnitude and minimum detectable size of satellites relative to the position of Bennu.

In Astrometrica:

Every point source (star) in each natural satellite search field will be detected and measured to a S/N of 2. Because of the possibility of scattered light from Bennu (which will be the brightest object in or near the search fields, by far) the limiting magnitude of the faintest detectable object will vary across some of the search fields.

In Excel:

The detected stars will be ingested into Excel. The data will contain the following information for each star: XY pixel within OCAMS image, J2000 RA/Dec coordinate, position relative to Bennu in J2000 coordinate system, measured V magnitude, stellar catalog V magnitude. The faintest stars detectable at different parts of the satellite search region will be used to determine the limiting magnitude. These limiting magnitudes will then be converted to a minimum satellite diameter using the algorithms described below (assuming an albedo of 0.03 and a spacecraft-satellite distance equal to the spacecraft-Bennu distance).

$$D(km) = \frac{1329}{\sqrt{\rho}} \, 10^{-0.2H}$$

where D(km) is the diameter of the satellite in km, ρ is albedo and H is the absolute magnitude (normalized to a distance of 1 AU from the Sun and observer and a phase angle of 0°). Equation from Pravec and Harris (2007).

$$H = V - 5log10(\Delta * r) - (0.04 * \alpha)$$

where V is the apparent magnitude of the satellite in the V photometric band, Δ is the distance between the spacecraft and satellite in AU, r is the distance between the Sun and satellite in AU, and α is the phase angle in degrees.

The diameter in km is then converted to cm via multiplication by a factor of 100,000.

$$D(cm) = D(km) * 100,000$$

In COTS plotting tool:

A plot of the region around Bennu will be produced showing the limiting magnitude for a S/N of 2 detection. A second plot showing showing the minimum natural satellite diameter in cm will also be produced.

Proposed software:

Astrometrica

Microsoft Excel

COTS plotting software

Additional references:

McFadden et al. 2016. Vesta's missing moons: comprehensive search for natural satellites of Vesta by the Dawn spacecraft. Icarus 257, 207-216.

Pravec and Harris. 2007. Binary asteroid population 1. angular momentum content. Icarus 190, 250-259.