Extending a Spectroscopic Survey of Main Belt Asteroids with Micro Telescopes: A Proof of Concept Project

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By way of explanation…

- **Large Telescope**
- **Small Telescope**
- **Micro Telescope**
Origin of Project

Outgrowth of red-shift labs run for UC Riverside

Use of SBIG DSS-7 / ST-7XME combo leads to curiosity about its application to asteroids

Initial experiments on a couple bright (±10 mag) asteroids were intriguing

After sharing the results with Brian Warner, he suggests review of 2002 papers by Schelte Bus and Richard Binzel that proposed taxonomy based on slope values over segments of the spectral curve
Key First Steps

- Decide on name and acronym
  - Goat Mountain Asteroid Spectrographic Survey
  - GMASS

- Design logo

- Order t-shirts

- Contemplate project approach & methodology
Bus & Binzel publish two papers in 2002 that are based on the spectrographic observation of over 1400 asteroids from Kitt Peak.

The papers describe both the observations and the development of a taxonomy for asteroids.

Phase II of the Small Main-Belt Asteroid Spectroscopic Survey

The Observations

Schelte J. Bus¹ and Richard P. Binzel

Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139
E-mail: sjb@ifa.hawaii.edu

Received March 13, 2001; revised February 15, 2002
Bus & Binzel propose a classification system that is based on 26 different color curves and seeks to refine D. Tholen’s C-S-X taxonomy (below)
The Bus & Binzel work was based on the Small Main-belt Asteroid Spectrographic Survey, or SMASS, conducted in the early 1990s by MIT at Kitt Peak on telescopes of 2.4 and 1.3 meters.

The spectral data was subject to a rigorous calibration methodology that had to be duplicated by the authors.
GMARS (Goat Mountain Astronomical Research Station – G79) is a 10-acre facility in the high desert of Southern California where, between them, the authors have three observatories, all equipped with .36 meter catadioptic telescopes.
Hardware: Spectrograph

The SBIG DSS-7/ST-7

Strengths
- Light weight
- Ease of operation

Shortcomings
- Range cuts off at 0.750 $\mu$m
- Cannot autoguide through spectrograph
Hardware: Telescopes

C-14 on Paramount
Provided hi-precision GOTO and tracking for good productivity

Meade LX200R
Provided lots of frustration and unwelcome opportunities for humor
Software for Capture

CCDOPS (Windows)
Provided needed functionality but inefficient workflow

Equinox Image (Mac)
Was modified to provide good functionality and easy operation
Operational Considerations

Target acquisition issues

- GOTO pointing was never good enough to reliably put target on 100 micron slit

Obtaining spectra of moving objects

- Time exposures compromised by asteroid movement during the capture

Capturing solar analog stars & reference spectra

- Suitable targets were not always available at comparable air masses
Operational Considerations

Truncated spectral range
- Longest wavelength that could be reliably captured was 0.750 $\mu$m – far short of SMASS limit of 0.9250 $\mu$m

High solar phase angle (20° or more) may have contributed to reddening

Air mass of solar analog stars and targets
- Asteroids best observed in the Fall when higher in the sky. By Spring, the ecliptic is low creating higher air mass for most main belt asteroids.
Sample Group of Asteroids

Spectra of 22 asteroids were captured from February to April 2009; after processing, eight were determined to have sufficient S/N to use

<table>
<thead>
<tr>
<th>Asteroid</th>
<th>Date (2009)</th>
<th>Phase Angle</th>
<th>Magnitude</th>
<th>Air Mass</th>
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<td>1 Ceres</td>
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Data for Samples from SMASS

The original SMASS data was found on a NASA site and converted to charts to match GMASS data.
Software for Analysis

Calibration and data analysis performed in Visual Spec 3.6.1

Allowed authors to process data in more user-friendly environment than IRAF (used by SMASS)
Target spectra brought into VSpec and calibrated using emission lines from planetary nebula.
Spectra Processing

Target spectra is divided by the solar analog star
Spectra is then calibrated for flux by reference star.
Spectra Processing

Data is exported from VSpec into MS Excel where it is normalized, smoothed and charted.

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Results: Comparison to SMASS

27 Euterpe
- Data Captured at GMARS by Stephens-Magna
- Data Processed Per Bus-Binzel Methodology
- Color Curve by Bus-Binzel from SMASS Data

1 Ceres
- Data Captured at GMARS by Stephens-Magna
- Data Processed Per Bus-Binzel Methodology
- Color Curve by Bus-Binzel from SMASS Data
Results: Comparison to SMASS
Results: Comparison to SMASS
Conclusions

Although noisier than the SMASH data, and limited by the spectral range of the DSS-7, most of the curves generated by GMASS compared favorably to those used by Bus & Binzel.

With refinements to the capture techniques and instrumentation, the authors believe that microtelescopes in the .35-.40 meter range could be used to support the classification of asteroids using Bus & Binzel’s taxonomy down to 14th magnitude, or fainter.
Conclusions

Amateur contributions could be follow-up to SMASS (which was mostly single-night observations), as well as provide expansion of the database for surveyed asteroids.

Additional data could permit more nuanced categorization of asteroids and understanding of their dynamical families.
Future Work

Authors are examining options for off-the-shelf spectrographs that would address the same range as SMASS (0.40 to 0.925 \(\mu m\))

Refinement of software/workflow to permit semi-automated (scripted?) processing of data

Contemplation of grant-supported project to purse systematic data collection on targets as faint as 15\(^{th}\) magnitude

Unresolved issue: Repository for data?